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An analysis of humidity measurements in the upper troposphere and lower stratosphere over Southern England

by

G. B. Tucker

(Meteorological Office)

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An analysis of humidity measurements in the upper troposphere and lower stratosphere over Southern England

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Summary

399 high altitude ascents measuring temperature and frostpoint, made by aircraft of the Meteorological Research Flight, are analysed and the results compared with previous conclusions. Before 1954 observations were made from a Mosquito aircraft and ascents seldom exceeded the 200 mb level; from 1954 onwards a Canberra aircraft was used and the 125 mb level was regularly attained.

Little systematic difference is detected between the mean of the Canberra ascents and that of other aircraft. The extreme dryness of the stratosphere is a feature of all seasons, but summer is the most moist season (in terms of water content) in the stratosphere as well as in the troposphere. Above about 500 mb the humidity mixing ratio lapse decreases with height, and above 150 mb the humidity mixing ratio levels out to about .002 g/Kg. The tropopause does not coincide with any marked discontinuity in frostpoint or humidity mixing ratio. An attempt to represent the observed distribution of water vapour in the vertical as a balance between vertical eddy diffusion and vertical motion is found to be inadequate. An earlier suggestion (1) - that at any fixed level above or below the tropopause the frostpoint is lower if the tropopause is low - is confirmed. A graphical method is devised to show the inter-relationships between season and the temperature, frostpoint and pressure at the tropopause. Finally an attempt to relate the frostpoint to the jet-stream proves to be largely unsuccessful.

1. Introduction

At the end of 1955 observations of temperature and frostpoint had been made on 399 high altitude ascents (begun in 1943) over Southern England by aircraft of the Meteorological Research Flight. The earlier ascents (130, up to June, 1950) have been analysed by Bannon, Frith and Shellard (1). This paper is a continuation of that work using all 399 ascents. The following analysis is not as exhaustive as (1) and, although an essentially similar method of processing observations is involved, in some cases the material has been handled differently.

The type and method of observation together with the instrumentation and estimates of accuracy have been dealt with elsewhere (1, 2, 3). Murgatroyd, Goldsmith and Hollings (2) have also analysed the first 21 flights (begun in 1954) by a Canberra aircraft, while Helliwell, Mackenzie and Kerley (4) have made a similar analysis of 46 such ascents in 1955. The Canberra soundings have usually attained 48,500 ft (125 mb): of the 399 ascents considered below, 85 Canberra soundings are included. Earlier Mosquito flights did not exceed 38,600 ft (200 mb).

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The analysis is divided into five sections:-

(i) ascents are presented in chronological order and the preliminary processing of individual soundings is described;

(ii) mean seasonal and annual values of temperature, frostpoint and humidity mixing ratio are evaluated at standard pressure levels; Canberra and other aircraft observations are distinguished for comparison;

(iii) a discussion of the vertical distribution of frostpoint relative to the tropopause;

(iv) an attempt to relate the seasonal variations of frostpoint, temperature and pressure at the tropopause;

(v) the vertical structure of frostpoint is considered in relation to the jet-stream.

2. Data

From the original ascent curves, values of temperature (T) and frostpoint (F) at standard pressure levels (700, 500, 400, 300, 250, 200, 150 and 125 mb) were extracted and tabulated in chronological order (Table 1), together with the selection of tropopause for each ascent. These were done partly by the Upper Air Climatology Branch and partly by the Meteorological Research Flight. These data are recorded on punched Hollerith cards, one card for each ascent. Much of the sorting and tabulating was done mechanically. The soundings prior to July, 1950 have been published previously (1) and only values for July, 1950 to December, 1955 are given in Table 1. Although the approximate position of the ascent is quoted it has been decided to regard these figures as appertaining to 'Southern England' because the area over which the atmosphere is sampled, especially since the use of the Canberra aircraft, is so large. The observations were classified according to air mass and circulation (as in Geophysical Memoir No. 88 (1)) by the Upper Air Climatology Branch and, although not analysed below, these classifications are included in Table 1.

The recommended international classification of 'tropopause' was used:- /

(i) the "first tropopause" is defined as the lowest level at which the lapse rate decreases to 2°C/Km or less, provided also that the average lapse rate between this level and all higher levels within 2 Km does not exceed 2°C/Km;

(ii) when, above the first tropopause, the average lapse rate between any level and all higher levels within 1 Km exceeds 3°C/Km, then a "second tropopause" can occur and is defined by the same criteria as in para. (i). This tropopause can either be above or within the 1 Km layer;

(iii) further tropopauses are defined at higher levels by the same criteria as in para. (ii).

For the sake of continuity and to afford comparison the seasons are defined as in G.M.88 (1):-

Winter - January, February, March.
Spring - April, May, June.
Summer - July, August, September.
Autumn - October, November, December.

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3. Seasonal and annual mean values of temperature and frostpoint at standard pressure levels

Observations at the 150 and 125 mb levels began with Canberra aircraft in January, 1954. It was necessary to determine whether the discrepancy suggested by Murgatroyd et al. (2) between the first observations made by Canberra aircraft and those given in Geophysical Memoir No.88 (1) is also a feature of subsequent Canberra observations. (Murgatroyd et al. found frostpoints considerably lower than those given in Geophysical Memoir No.88, above a level with a pressure 50 mb less than the tropopause pressure. They suggested that this may be due to an instrumental error in the earlier observations).

Table II presents the mean seasonal values of T and F at standard pressure levels together with the number of observations. The differences between Canberra and pre-Canberra means are shown graphically in Figure 1. No systematic differences occur apart from:-

(i) the lower levels in spring where the negative anomalies of both T and F coupled with the small number of observations suggested that a difference in sampling is the reason;

(ii) the highest levels where the pre-Canberra soundings record slightly warmer (autumn and winter) and moister (all seasons) conditions in the stratosphere.

The mean seasonal curves are shown in Figure 2 with the number of observations entered at each point. (The curves are not drawn through the points representing the mean values for the tropopause; these points are obtained by averaging pressures and temperatures at the tropopause and would not necessarily be expected to lie on the true mean curves of temperature against pressure. See, e.g., the winter curves where the mean pressure of the tropopause is near 250 mb). Values for 200, 250 and 300 mb from Geophysical Memoir No.88 are shown and, with the exception of autumn, when relatively few observations were made (in G.M.88), the agreement is good. The divergence of the curves above the tropopause proves to be a feature of the mean values as well as of the individual ascents, and the mean frostpoint shows a tendency to become asymptotic to about -120°F. with increasing height - agreeing with the results of (2) and (4). These features are also characteristic of the mean annual curve, Figure 3.

An interesting seasonal feature is revealed when the frostpoint differences between summer and winter are plotted (Figure 4); they show that the atmosphere in summer is moister* than in winter in the lower stratosphere as well as the troposphere; the summer-winter amplitude of F is 15 to 20°F in the troposphere but however only 0 to 5°F in the stratosphere. The frostpoint depressions in Figure 5 also show that while the stratosphere in summer is systematically of lower relative humidity, the seasonal difference in frostpoint depression is only about 10°F, compared with actual frostpoint depressions of 40 or 50°F. These points are better illustrated in Table III which gives the mean seasonal and annual relative humidities and humidity mixing ratios at standard pressure levels. The lower stratosphere although having a higher moisture content in summer has a lower relative humidity. It should be noted however that although summer is moister than winter, both spring and autumn are drier than winter. Any definite seasonal trend in water content is masked by the variations in the average tropopause pressures (Table III) which may not be representative of the seasons. The humidity mixing ratios for winter, summer and the year have been plotted logarithmically against a linear height scale in Figures 6A, B and C together with values obtained by Barrett (5) from three single soundings. Barrett's figures which refer to ascents over Central North America are shown to be very different from mean conditions in the lower stratosphere over England.

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* 'moister' here and throughout the analysis refers to water content and not to relative humidity.

4. Temperature and frostpoint in relation to the tropopause

The aircraft soundings were too spasmodic in time for unweighted means of T and F at various pressures above and below the tropopause to be representative of mean conditions. To overcome this ascents were grouped according to tropopause height, each group covering a range of 2000 ft on the I.C.A.N. scale, as in the following table.

Tropopause groups	Pressure range in mb (pressure at tropopause)	Height range in 1000 ft I.C.A.N.
1	less than 147	greater than 45
2	162-148	45-43
3	179-163	43-41
4	197-180	41-39
5	216-198	39-37
6	238-217	37-35
7	262-239	35-33
8	287-263	33-31
9	315-288	31-29
10	344-316	29-27
11	376-345	27-25
12	410-377	25-23

Mean values of T and F at 25 mb intervals above and below the tropopause in each group were extracted and weighted according to the frequency of tropopause height over Larkhill for the whole year and for the four seasons separately for the period 1946-1950 (6). Only rough weighting factors were considered necessary for the accuracy required; they are given in the following table.

Weighting factor

Tropopause group	1	2	3	4	5	6	7	8	9	10	11	12
Winter	0	1	3	6	7	5	4	3	2	1	0	0
Spring	0	1	2	5	7	6	5	3	2	1	1	0
Summer	0	1	2	6	8	7	5	2	1	0	0	0
Autumn	1	2	3	5	6	5	4	3	2	1	1	0
Annual	1	4	10	23	27	24	18	11	6	3	2	1

Because the soundings in each season for tropopauses outside the range of groups 3 to 9 are so few they may not represent average high and low tropopause conditions; this together with their low weighting factor has led to their omission in the calculation of seasonal mean values. The weighted means are presented in Table IV and graphed in Figures 7A to 7E. For the annual means, values for Canberra ascents alone (similarly weighted) have been included. The curve of summer minus winter frostpoint differences (Figure 8A) shows the same features as Figure 4 except that at very high levels the winter stratosphere tends to be slightly moister than summer. However summer and winter frostpoint depression curves (Figure 8B) show similar values in the troposphere but in the lower stratosphere the summer depressions are some 10 to 15°F greater than in winter.

The dryness of the air in the lower stratosphere has been appreciated for some years and Brewer (7) suggests that this dryness is maintained by a large scale meridional circulation. By neglecting horizontal advection, considering a steady state and utilizing the concept of a vertical eddy diffusion coefficient

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embracing the whole of the turbulence spectrum, Brewer develops an equation -

$$K \frac{\partial^2 r}{\partial z^2} + w \frac{\partial r}{\partial z} = 0$$

where K is the eddy diffusion coefficient,

r is the humidity mixing ratio,

w is the vertical velocity downwards,

z is height above the tropopause.

The solution is $r = r_o + (r_t - r_o)\exp - wz/K$; the suffix 'o' refers to dry air aloft and suffix 't' to the tropopause value. Fitting curves to 16 early ascents into the stratosphere, and taking $K = 10^3$, he obtains a value for w of about 25 m/day (corresponding to a necessary cooling by radiation of 0.25°C/day).

Recently acquired knowledge of the lower stratosphere maintains the importance of horizontal advection, and the use of a K to embrace <u>all</u> eddy sizes smaller than the meridional circulation may not be realistic. Notwithstanding this, it is interesting to fit curves, similar to Brewer's, (Figure 9A, B, C and D) to values of humidity mixing ratio obtained from values of T and F in Table IV, and to compare the values of w thus derived with those of Brewer (using his value $K = 10^3$). The observed and theoretical values of humidity mixing ratio are given in Table V; the height scale in Figure 9 assumes an isothermal stratosphere. The values of w/K are derived from estimated values of r_o and F as in the following table:-

	<u>Winter</u>	<u>Spring</u>	<u>Summer</u>	<u>Autumn</u>	
r_o	.00250	.00210	.00251	.00250	g/Kg
F	-115.5	-117.4	-115.5	-115.5	°F
w/K	1.1	1.3	1.5	1.2	($\times 10^{-5}$ c.g.s.)

(Estimated r_o was the lowest value obtained, and F was estimated by assuming r_o to apply at 100 mb.)

These values are roughly one-half of those of Brewer, and correspond to a downward vertical velocity of about 10-15 m/day and require a radiative cooling of about 0.1-0.15 °C/day. The actual mean seasonal radiative cooling is estimated to be an order of magnitude higher (8) - which serves to indicate the inadequacy of this explanation.

Early sampling of the lower stratosphere has been criticised because of selectivity in favour of low tropopauses. The mean profiles of T and F for the ranges of tropopause-height (grouped as in the table on p.4) were calculated and the annual values are plotted in Figure 10. For clarity only the even numbered groups are plotted for about 150 mb above and below the tropopause. The conclusions of a similar but less detailed analysis in Geophysical Memoir No.88 are borne out, namely:-

(i) the higher the mean tropopause the lower the air temperature at the tropopause;

(ii) the higher the mean tropopause the lower the frostpoint at the tropopause;

(iii) at any specified pressure interval above or below the tropopause, the frostpoint is low if the temperature is low.

The variation with height of any frostpoint discontinuity occurring at the tropopause was investigated by calculating the values of $\partial F/\partial z$ in the 25 mb interval above and below the tropopause for each seasonal/tropopause height group (Table VI). These results show that no definite relationship exists between $\partial F/\partial z$ and the tropopause pressure in this series of observations.

5. Frostpoint and temperature at the tropopause

It was interesting to investigate the relation between the variation with season of temperature (T_c), frostpoint (F_c) and pressure (P_c) at the tropopause. Correlation coefficients for two such relationships were calculated in Geophysical Memoir No.88 (1); they were

	Correlation coefficient	No. of pairs
$T_c : P_c$	+.77	106
$F_c : P_c$	+.51	106

There appears to be no reason why the relationship should be linear, and before resorting to any more complex statistical analysis a graphical relationship has been attempted with dot diagrams to illustrate qualitatively the reliability of the results. The basis of this study was the grouping into tropopause pressures for each season (Section 3), and from this:-

(i) the mean tropopause temperature, frostpoint and pressure in each group were calculated;

(ii) a diagram was drawn showing the variation of T_c and P_c with season (Figure 11); along each seasonal ordinate the mean tropopause temperature (T_c) in each of the tropopause groups 3 to 9 is plotted at the mean pressure (P_c) of the group;

(iii) a similar diagram for F_c and P_c is given in Figure 12;

(iv) Figure 13 shows the variation of F_c and T_c with season; along each seasonal ordinate the mean tropopause frostpoint (F_c) in each tropopause group is represented as a function of the mean temperature (T_c) of the group. This was done by combining the smoothed values of T_c as a function of P_c (Figure 11) and F_c as a function of P_c (Figure 12) along each seasonal ordinate to produce F_c as a function of T_c - with the implicit assumption that F_c is a single valued function of T_c.

(N.B. The tropopause pressure groupings afford a graphical means of drawing a mean curve to represent F_c as a function of T_c without assuming linearity as would a regression equation.)

In order to obtain an estimate of the deviation of individual observations from the means expressed in Figures 11, 12 and 13, dot diagrams of individual values of T_c and F_c were drawn up for each tropopause pressure group for each season (Figure 14). The points $\bar{T}_c$, $\bar{F}_c$ are indicated by crosses and are consistent with Figure 13. The deviations of individual points from this value in the vertical represent the scatter about the mean values plotted in the $\bar{F}_c$ ($\bar{P}_c$, season) diagram, Figure 12, the deviations in the horizontal similarly represent the scatter for the $\bar{T}_c$ ($\bar{P}_c$, season) diagram, Figure 11.

The dot diagram proves interesting in its own right, e.g., illustrating the proximity of each cluster to saturation (the 100 and 50 per cent relative humidity lines have been drawn in each case). The three ascents showing supersaturation have been plotted (Figure 15): the 1950 and 1952 values appear realistic and saturation was reported in a cirrus environment; but the earlier (1948) ascent must be treated with scepticism.

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6. Frostpoint and the jet-stream

Circulations in the vertical plane at right angles to the jet axis have been the subject of several recent investigations (9, 10, 11). An attempt was made to utilize these frostpoint measurements to obtain the humidity distribution about the jet axis and to use it as a tracer element to deduce vertical motion. This was not successful but the method of approach and one result are described briefly below.

The 300 mb charts in the Daily Aerological Record were used to determine the distance from a jet axis of each ascent (a jet-stream was defined as a stream in which the wind speed exceeded 85 kt at 300 mb). If the ascent was within 500 miles of a jet axis it was included in one of five 200-mile range-groups (i.e., 500 to 300, 300 to 100, +100 to -100 etc. miles relative to the axis). Entrances, centres and exits of jet-streams were studied individually making fifteen groups in all. The mean ascent for each group was then calculated and the mean tropopause height, H, was noted. This mean ascent was then compared with a 'weighted average'+ ascent obtained by compounding the average seasonal ascents for the tropopause height H, obtained from Table I, weighted according to the total number of ascents in each season.

Three attempts were made to classify into range-groups according to distance from the jet-stream axis:

(i) by referring each ascent to the current synoptic situation,

(ii) by taking the mean over the preceding 12 hours of the position of the air relative to the jet-stream by drawing trajectories at 300 mb,

(iii) by choosing examples of well-defined jet-streams from (ii).

Of these three attempts the answers of the last were most coherent but even these have little significance. They are expressed in the form of a diagrammatic table (Figure 16). The 'classical' circulation at the jet entrance below the tropopause (9) can be distinguished, as can a reverse circulation at the exit. Elsewhere there is no systematic trend except a possible indication that in the lower stratosphere ascent occurs south of the entrance and north of the exit with a general subsidence at the centre (Figure 17). However it is obvious that little reliance can be based on the above conclusions, and that this method cannot compare with Murray's analysis (11) of observations obtained on special horizontal traverses of jet-streams.

+The 'weighted average'

It will be recalled that in Section 3 the ascents analysed in the paper were divided into the four seasons. The ascents in each season were grouped according to their tropopause height. Each of these tropopause height groups covered a range of 2,000 ft on the I.C.A.N. scale. The means of these groups were then obtained, arriving at a series of mean ascents which are effectively average seasonal ascents for various tropopause heights.

Reverting to the jet-stream analysis, the representative (mean) ascent within a certain distance of the jet axis must be compared with some sort of standard ascent purporting to represent the atmosphere undisturbed by jet-stream effects: the 'weighted average' ascent was chosen as the standard.

It is appreciated that this ignores the fact that the height of the tropopause may well be partially a result of the existence of the jet-stream.

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TABLE 1

Values of temperature and frostpoint at standard pressure levels, as obtained from aircraft soundings

(Listed in chronological order)

Date			Approximate position		Tropopause			Standard pressure levels																	
								700 mb		500 mb		400 mb		300 mb		250 mb		200 mb		150 mb		125 mb			
Year	Month	Day	Latitude (°N)	Longitude (°W except where otherwise stated)	Pressure (mb)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Air mass classification	Circulating classification
50	07	14	51	02	300	-44	-82	+27		- 7		-27	-60	-44	-82	-42	-115							1	5
50	07	18	51	02	216	-67	-84	+39	+15	+ 8	+ 7	-13	-19	-40	-50	-57	-71	-64	-94					4	2
50	07	19	51	02	205	-70	-87	+37	+34	+10	-38	-10	-53	-38	-40	-56	-68	-68	-93					4	2
50	07	24	51	02	205	-64	-93	+34	-17	+12	- 6	- 6	-22	-35	-42	-51	-67	-65	-94					8	2
50	07	25	51	02	239	-60	-80	+35	+26	+ 5	-51	-16	-61	-42	-72	-56	-77	-57	-99					8	2
50	07	28	51	02	228	-65	-80	+33	+19	+ 4	-39	-15	-41	-44	-60	-60	-73							8	2
50	07	31	51	02	227	-63	-87	+29	+18	+ 2	-26	-19	-44	-48	-72	-60	-82	-56	-100					8	2
50	08	01	51	01	238	-63	-91					-20	-21	-44	-50	-59	-90							1	3
50	08	02	51	02	330	-50	-69	+21	+13	-12	-33	-34	-45	-51	-79	-44	-101							1	3
50	08	03	51	02	238	-57	-71	+34	+12	- 3	-40	-26	-55	-39	-61	-55	-70	-52	- 72					6	2
50	08	08	51	02	200	-68		+35	+35	+11	+10	- 7	-11	-35	-37	-49	-66	-68	- 98					7	4
50	08	09	51	02	205	-66	-81	+37	-16	- 7	-31	-13	-59	-34	-44	-51	-64	-66	- 85					8	3
50	08	10	51	02	262	-53	-84									-53	-89	-55	-109					6	5
50	08	14	51	02	228	-71	-72	+34	+ 4	+ 6	-30	-15	-44	-44	-45	-63	-63	-58	- 90					8	6
50	08	14	51	02	228	-71	-72	+34	+ 3	+ 5	-30	-16	-45	-44	-45	-61	-61	-56	-105					8	6
50	08	18	51	02	286	-59	-67	+22	+14	- 7	-11	-28	-28	-55	-60	-57	-83							1	3
50	08	21	51	02	215	-66	-86					-18	-61	-43	-75	-59	-77	-66	- 96					7	4
50	08	22	51	02	179			+35		+ 8	-20	-15	-18	-42	-50	-59	-68	-74	- 88					2	4
50	08	29	51	02	262	-61	-76	+22	+17	- 5	-28	-25	-50	-51	-62	-61	-80	-54	-104					2	2
50	08	30	51	02	237	-70	-77							-53	-57	-68	-77	-56	- 92					4	2
50	09	04	51	02	183			+44		+12		- 7	-42	-35	-55	-52	-76	-71	- 83					4	8
50	09	05	51	02	262	-63	-58	+34	-42	+ 5	-47	-22	-57	-47	-54	-64	-73	-65	-100					8	6
50	09	15	51	02	301	-61	-65	+22		- 9	- 1	-32	-37	-61	-65	-45	-104							1	5
50	09	18	51	02	250	-59	-90	+22	-22	+ 3	-55	-15	-26	-43	-55	-58	-90	-55	-108					6	2
50	09	19	51	02	287	-53	-75	+29			-18	-22	-64	-48	-70	-55	-85	-54	- 97					2	4
50	09	25	51	02	301	-51	-76	+22	+13	-12	-20	-34	-47	-51	-77	-46	-103							1	3
50	09	26	51	00	250	-55	-101	+21		- 8		-30		-47	-82	-55	-101	-56	-112					8	2
50	09	29	51	02	190			+33	+29	+ 8	- 3	-12	-26	-35	-66	-53	-76	-71	- 94					4	1
50	10	10	51	02	250	-61	-72	+21	+14	- 8	-12	-25	-42	-49	-64	-61	-72	-59	- 76					8	2
50	10	11	51	02	180			+26	+10	+ 5	- 2	-15	-27	-42	-49	-57	-64	-74	- 85					7	6
50	10	12	51	02	191	-78	-88	+38	+ 6	+ 9	-49	-13	-42	-39	-58	-55	-70	-76	- 81					4	6
50	10	17	51	02	159			+36	+30	+10	- 1	-11	-20	-37		-55		-76						4	2
50	10	17	53	00	188			+35	+ 1	+11	- 1	-13		-39		-57		-74						8	2
50	10	18	51	02	123			+36	+ 4	+ 8	-32	-14	-44	-40	-71	-53	-80	-69	- 92					4	1
50	10	19	51	02	175			+39	+18	+ 9	- 7	-14	-30	-39	-63	-56	-77	-75	- 81					4	1
50	10	19	53	00	178			+38	+34	+ 7	- 3	-17	-30	-39	-68	-56	-74	-75	- 87					4	1
50	10	21	51	01	205	-79	-86	+35	+20	+ 1	- 3	-19	-25	-48	-59	-65	-68	-79	- 87					8	1
50	10	22	51	01	228	-75	-83	+29	+15	- 4	-11	-26	-32	-51	-59	-67	-75	-72	- 95					8	2
50	10	24	51	02	205	-78	-92	+29	+17	- 2	-21	-22	-42	-51	-60	-67	-83	-76	- 98					1	2
50	10	24	53	00	227	-74	-86	+31	+11	0	-31	-24	-47	-60	-72	-66	-85	-77	- 88					1	2
50	10	25	53	00	238	-73	-89	+27		+ 7		-29		-52		-67	-82	-73	- 89					1	2
50	10	25	51	02	250	-69	-75	+31	-38	+ 4	-59	-26	-67	-53	-69	-69	-75							1	2
50	10	26	51	01	207	-72	-93	+26	-51	- 6	-42	-28	-76	-48	-66	-60	-76	-72	- 97					1	2
50	10	26	51	01	228	-71	-82	+23	-39	- 7	-35	-27	-67	-46	-58	-59	-70	-75	- 93					1	2
50	11	14	51	02	315	-52	-86	+ 9	- 2	-20	-52	-40	-66	-53	-88	-54	-102							1	2
50	11	17	51	01	315	-58	-73	+10	-31	-15	-43	-35	-49	-49	-82	-59	-97	-55	-109					1	2
50	11	28	51	02	288	-58	-76	+23	-12	- 6	-51	-29	-62	-56	-68	-59	-97	-63	-113					8	3
50	11	29	51	02	343	-51	-65	+12	+ 7	-18	-25	-39	-51	-56	-92	-55	-95							1	3
50	12	07	51	02	238	-70	-95	+11	-24	- 6	-56	-27	-50	-50	-70	-64	-87	-67	-111					6	2
50	12	08	51	02	158			+23	+ 6	- 2	-16	-23	-61	-50	-68	-65	-82	-81	- 94					7	8
50	12	11	51	02	345	-58	-72	+ 5	-13	-28	-35	-48	-54	-54	-84	-53	-106	-57	-112					1	3
51	01	12	51	02	344	-65	-68	+ 9	-14	-27	-40	-51	-51	-57	-91	-51	-106							1	3
51	01	24	51	02	273	-75	-85	+15		-17		-40		-69	-70	-69	-93	-64	-119					7	2
51	02	07	51	02	300	-55	-82	+10	-11	-15	-34	-34	-45	-55	-82	-53	-89	-52	- 90					1	2
51	02	15	51	02	286	-67	-75	+ 8	0	-22	-36	-41	-47	-64	-72	-60	-97	-53	-102					6	5
51	02	19	51	02	376	-53	-63	+ 9	-11	-26	-37	-48	-49	-60	-85	-50	-88	-46	-106					1	2
51	02	23	51	02	314	-62	-76	+ 6	- 6	-22	-48	-40	-64	-61	-83	-60	-91	-61	- 96					1	2
51	03	01	51	02	239	-77	-83	+25	- 5	- 7	-19	-29	-37	-57	-65	-74	-79	-75	- 96					7	6
51	03	09	51	02	215	-83	-91	+19	- 2	-11	-33	-32	-42	-60	-72	-75	-86	-76	- 98					3	2
51	03	14	51	02	330	-53	-83	+13	-22	-20	-39	-41	-55	-56	-88	-54	-93	-59	- 93					1	3
51	03	15	51	02	228	-72	-87	+20	-21	-12	-29	-34	-47	-54	-73	-67	-84	-71	- 93					6	2
51	03	17	51	02	315	-57	-82	+19	+ 5	-18	-26	-40	-51	-56	-85	-60	-93	-62	- 91					4	4
51	03	19	51	02	329	-65	-70	+11		-22	-36	-45		-58	-91	-52	-91	-53	- 90					1	3
51	04	05	51	01	228	-79	-86	+21		- 7	-49	-29	-48	-58	-58	-72	-79	-72	-102					3	8
51	04	10	51	02	315	-61	-78	+ 7		-24		-43	-60	-60	-87	-51	-108							1	2

M.R.P. 1052

Date			Approximate position		Tropopause			Standard pressure levels																	
								700 mb		500 mb		400 mb		300 mb		250 mb		200 mb		150 mb		125 mb			
Year	Month	Day	Latitude (°N)	Longitude (°W except where otherwise stated)	Pressure (mb)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Air mass classification	Circulation classification
51	04	13	55	02	344	-56	-76	+ 6		-29	-41	-46	-71	-52	-95	-49	-105							1	3
51	04	17	51	02	206	-82	-93	+24	-31	- 6	-24	-27	-37	-54	-59	-71	- 77	-83	- 95					6	6
51	04	18	51	02	216	-80	-89	+24	+24	- 6	-10	-25	-32	-54	-60	-71	- 77	-79	- 95					6	6
51	04	19	51	02	217	-82	-87	+25	+20	- 5	-26	-22	-62	-53	-71	-71	- 74	-80	- 96					6	6
51	04	23	51	02	164			+32	- 6	+ 5	-18	-20	-45	-49	-52	-63	- 79	-81	- 92					8	1
51	04	24	51	02	173			+33	+ 5	+ 4	-35	-19	-48	-47	-66	-63	- 79	-80	- 86					4	1
51	05	07	51	02	262	-69	-81	+22	0	-10	-38	-33	-56	-61	-68	-68	- 84	-60	-113					1	2
51	05	08	51	02	315	-55	-77	+ 7		-18		-37	-61	-54	-90	-54	- 98	-52	-110					1	5
51	05	15	51	02	238	-74	-76	+24	+16	- 6	-12	-27	-34	-52		-69	- 74	-69	- 93					4	6
51	05	25	51	02	261	-67	-72	+24	+14	- 4	-47	-27	-31	-55	-56	-66	- 88	-59	-109					2	5
51	05	28	51	02	300	-53	-85	+21	+16	- 8	-20	-30	-44	-53	-85	-53	-102							2	3
51	06	08	51	02	216	-73	-79	+31	- 1	0	- 5	-19	-54	-45	-48	-61	- 71	-68	- 90					6	2
51	06	11	51	02	227	-67	-73	+33	+27	- 4	-37	-18	-45	-45	-54	-62	- 62	-66	- 78					4	8
51	06	20	51	02	228	-71	-82	+28	- 8	- 1	-18	-22	-42	-49	-69	-64	- 78	-67	- 95					2	2
51	06	28	51	02	238	-67	-77	+29	-18	+ 3	-48	-18	-40	-48	-55	-66	- 70	-61	-107					8	5
51	06	29	51	02	250	-59	-84	+20		+ 3	-10	-20	-37	-48	-69	-59	- 84							8	5
51	09	04	51	02	170			+49	+ 2	+18	-30	- 3	-29	-30	-49	-49	- 56							4	1
51	09	21	51	02	165			+40	+ 1	+10	-19	-14	-37	-40	-54	-56	- 68	-72	- 84					2	1
51	09	26	51	02	194							-20	-33	-45	-54	-57	- 77							7	2
51	11	07	51	02	273	-68	-79	+25	+ 8	- 8	-26	-32	-47	-59	-63	-66	-100	-65	-103					2	3
51	11	12	51	02	272	-58	-67	+25	- 4	-10	-28	-31	-56	-51	-64	-59	- 83	-59	-103					2	2
51	11	26	51	02	227	-76	-82	+20		-11		-33		-54	-64	-68	- 74							7	1
51	11	26	51	02	215	-80	-99	+21	-14	- 9	-28	-30	-44	-51	-73	-70	- 91							7	1
51	11	26	51	02	190			+21	-12	-10	-34	-30	-50	-55	-71	-70	- 88	-87	- 95					7	1
51	11	29	52	03	115									-50	-79	-65		-87	-108					4	1
51	11	30	51	02	150			+31	+ 2	0	-24	-20	-46	-46	-70	-65	- 78	-84	-100					4	1
51	12	11	51	02	193			+27	-21	- 6	-24	-28	-39	-57		-71		-83						6	1
51	12	12	51	02	216	-75	-90	+27	-18	- 8	-17	-32	-37	-53	-72	-67	- 79	-75	- 92					6	7
51	12	17	51	02	200			+33	+ 4	- 1	-27	-24	-51	-53	-69	-63	- 80	-71	- 93					4	2
51	12	18	51	01	220							-20	-27	-50	-61									4	2
52	01	01	51	02	250	-73	-100	+ 7	-18	-27	-42	-43	-63	-59	-84	-73	-100	-69	-103					6	2
52	01	14	51	02	189			+23	-42	- 2	- 9	-19	-29	-49	-54	-62	- 69	-77	- 86					8	1
52	01	25	51	02	261	-79	-89	+ 3	- 6	-28	-42	-47	-56	-71	-79	-79	- 91	-73	-114						3
52	02	13	51	02	273	-74	-81	+ 4	-21	-23	-34	-42	-45	-69	-69	-75	- 93	-75	-104					5	2
52	02	19	51	02	216	-81	-94	+17		- 9		-32	-68	-59	-90	-75	- 95	-79	-102					2	6
52	02	29	51	02	180			+26	+20	0	- 6	-21	-26	-49	-53	-67		-89						4	1
52	03	04	51	02	315	-56	-83							-54	-90	-46	-102							1	2
52	03	11	52	04	223									-56	-68	-73	- 80							8	1
52	03	18	51	01	328	-51	-85	+15		-20	-34	-40	-66	-53	-92	-56	- 93	-57	- 97					2	3
52	04	01	53	02	360	-52	-65	+ 2		-24	-36	-42	-57	-55	-73	-52	- 73							1	5
52	04	02	51	01	360	-56	-72	+ 2	-16	-27	-50	-46	-62	-54	-88	-43	- 93							1	2
52	04	04	51	02	228	-76	-95	+22	-30	-13	-55	-34	-67	-61	-82	-73	- 92							2	8
52	04	22	51	02	344	-55						-41		-53	-88	-45	- 99							1	3
52	04	23	51	02	392	-44	-54	+10	- 4	-23	-43	-42	-53	-41	-77	-45	- 78							1	5
52	05	06	51	01	287	-61	-66	+21		- 9		-33	-43	-59	-69	-55	- 80							1	3
52	05	07	51	04	282	-50	-73	+12		-20		-36		-47		-47	- 78							1	2
52	05	16	51	01	180									-47	-77	-63	- 84	-82	- 94					2	1
52	05	20	51	01	250	-72	-75	+26	-20	- 3	- 8	-25	-29	-54	-57	-72	- 75	-66	- 99					2	2
52	05	21	52	01	227	-75	-81	+27		- 3	-30	-24	-50	-53	-59	-70	- 74	-70	- 96					2	1
52	06	16	51	02	198			+30	-14	+ 7	- 6	-15	-19	-41	-47	-60	- 65	-77	- 79					6	6
52	06	19	53	02	250	-66	-72							-52	-61									1	5
52	07	01	51	02	205	-66	-78	+44		+10	- 9	-11	-21	-39	-45	-56	- 72							4	4
52	07	03	51	01	215	-70	-76	+28		+ 5		-16		-39	-46	-59	- 62	-64						7	5
52	07	04	51	02	185			+42	+25	+12	- 9	- 8	-34	-34	-45	-54	- 63							7	2
52	07	10	52	01	185			+35		+10		-12		-35		-51	- 72							4	6
52	07	23	51	01	180			+39	+12	+11	-27	- 6	-37	-35	-51	-51	- 67							4	1
52	08	29	51	02	190			+44	+12	+12	-14	- 7	-24	-34	-38	-52	- 52							6	2
52	09	09	51	02	330	-54	-63	+19		-11		-34		-46	-83	-39	- 97							2	3
52	09	15	51	02	227	-69	-84	+34	-36	+ 2	-38	-20	-56	-46	-67	-61	- 76	-66	- 87					8	6
52	09	22	51	01	175			+37	+17	+10	-26	-11	-36											7	2
52	10	06	53	03	197			+33	-17	+ 5	-14	-14	-30	-41	-60	-57	- 70	-74	- 78					6	1
52	10	08	51	01	160			+37	+10	+ 3	-21	-19	-43	-48	-57	-65	- 67							1	5
52	10	10	51	01	301	-54	-72			-10	-49	-30	-59	-54	-72	-56	- 77							2	8
52	10	17	51	01E	216	-80	-79	+34	0	+ 3	-22	-20	-42	-51	-61	-69	- 69	-76	- 85					6	2
52	10	21	51	02	268			+27	- 8	- 3	-35	-27	-50	-53	-62									2	2
52	10	24	51	01	289	-42	-76							-41	-73	-43	- 78							2	3
52	10	29	51	02	349	-52	-62					-39	-52	-48	-81									2	5
52	10	30	51	01	300	-51	-76					-41	-47	-51	-76	-51	- 84							1	2
52	11	10	51	02	228	-75	-94	+29	+ 9	- 1	-27	-25	-33	-53	-57	-69	- 78	-74	- 80					2	6
52	11	12	53	02E	262	-69	-71	+19		- 9		-27	-32	-56	-66	-70	- 77	-69						7	6
52	11	13	51	02	228	-75	-96	+15	- 4	-12	-22	-29	-41	-57	-77	-70	- 82							7	3
52	11	20	51	01	360	-47	-81							-46	-95	-49	- 98							2	2
52	11	24	53	02E	287	-63	-73	+ 9		-11	-30	-30	-45	-60	-70	-66	- 86							8	2
52	11	25	51	02	239	-68	-72	+25		- 7		-29	-39	-55	-56	-66	- 66							8	2

Date			Approximate position		Tropopause			Standard pressure levels																	
								700 mb.		500 mb.		400 mb.		300 mb.		250 mb.		200 mb.		150 mb.		125 mb.			
Year	Month	Day	Latitude (°N)	Longitude (°W except where otherwise stated)	Pressure (mb.)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Air mass classification	Circulation classification
52	12	03	51	00	262	-60	-85	+19		-13		-35		-51	-76	-60	-88	-62	-102					6	6
52	12	17	51	02	345	-52	-66	+ 5	-11	-30	-55	-47	-67	-53	-76	-57	-84							1	3
52	12	19	51	01	280	-63	-69	+22		-10		-33		-59	-67	-60	-85							2	2
53	01	05	51	00	210			+20	-35	- 9	-42	-31	-50	-59	-60	-76	-77							6	2
53	01	20	51	02	200			+21	+ 2	-10	-37	-30	-60	-59	-64	-73	-79							4	1
53	01	22	51	02	231									-61	-66	-75	-77							4	1
53	02	02	51	02	238	-79	-92	+13		-15		-37		-64		-76	-87	-69						1	6
53	02	04	51	01	200			+19	-12	-12	-43	-35	-47	-60	-67									2	2
53	02	04	51	02	200			+16		- 9		-32		-61		-78	-78							2	2
53	02	06	51	02	239	-77	-93			-21	-45	-44	-57	-65	-83	-76	-93	-70	-106					1	3
53	02	13	51	02	261	-81	-104	+10		-17		-38		-68		-80	-108	-72	-133					6	1
53	02	16	51	01	238	-81	-87	+23	- 1	-11	-28	-30	-60	-59	-75	-76	-78	-82	-101					6	5
53	03	11	51	01	216	-83	-86	+19		- 7		-28		-55		-75	-75	-82	-92					6	4
53	03	13	51	01	206	-85	-90	+23	-10	- 8	-52	-29	-60	-57	-75	-72	-81	-83	-92					2	1
53	03	17	51	02	250	-76	-85	+20	-45	-16	-39	-37	-59	-64	-70	-76	-85	-74	-101					3	4
53	04	10	51	02	238	-76	-87	+16	-17	-12	-46	-33		-61	-76	-73	-83	-75	-103					6	1
53	04	14	51	02	300	-55	-79	+ 3	-28	-21	-62	-34	-67	-55	-79	-60	-90							1	3
53	04	17	51	02	274	-66	-77	+17	- 3	-11	-49	-32	-52	-60	-66	-62	-91							1	3
53	04	20	51	02	228	-74	-79	+25	- 1	- 8	-29	-30	-58	-55	-65	-67	-73	-69	-89					3	2
53	04	21	51	02	238	-73	-85	+28	- 4	- 7	-41	-29	-54	-56	-67	-71	-81	-66	-104					3	5
53	04	22	51	02	238	-71	-85	+26	+ 3	- 9	-27	-31	-50	-58	-73	-70	-82	-66	-100					3	1
53	04	23	52	01	262	-70	-75	+27	-20	- 9	-44	-30	-54	-59	-61	-70	-79	-65	-91					3	2
53	04	28	51	02	360	-57	-57	+12	+ 9	-21	-28	-44	-48	-52	-78	-47	-84							1	3
53	05	05	51	02	206	-82	-85	+29	+11	- 1	-21	-21	-41	-50	-65	-68	-75	-82	-87					4	1
53	05	06	52	01	213			+28	-23	0	-33	-22	-52	-50	-69	-68	-78							4	2
53	05	11	52	01	238	-73	-88	+25	- 6	- 7	-40	-29	-57	-55	-77	-70	-84	-66	-96					1	5
53	05	12	52	01	250	-73	-80	+23	+ 2	- 6	-34	-30	-47	-57	-69	-73	-80	-67	-102					1	5
53	05	19	51	02	239	-65	-75	+29	+11	- 4	-21	-24	-41	-52	-70	-63	-76							2	4
53	05	21	51	02	228	-75	-75	+30	+19	0	- 9	-20	-32	-49	-50	-67	-67	-66	-86					2	2
53	05	29	51	01	173			+32		+ 5	+ 3	-14	-15	-39	-39	-56	-57	-72	-101					7	2
53	06	09	51	01	238	-63	-83			- 4		-16		-45	-68	-60	-76	-66						1	2
53	06	10	51	01	238	-64	-82	+32	- 7	-12	-36	-14	-42	-45	-59	-59	-73	-62	-84					1	2
53	06	17	51	01	288	-60	-64			- 7	- 5	-30	-30	-58	-62	-49	-79	-46						1	3
53	06	18	51	01	300	-54	-71			- 7	-16	-30	-46	-54	-71	-51	-90	-47	-102					1	3
53	06	22	51	01	279			+29	+ 7	- 3	-30	-26	-36											2	3
53	06	22	51	01	330	-44	-56			- 3	-30	-25	-32	-43	-85	-42								2	2
53	06	23	51	01	260	-60	-68	+26	+26	+ 2	- 4	-19	-30	-48	-52	-56	-76							2	2
53	06	23	51	01	254			+29	+17	+ 1	-30	-20	-40	-49	-56									2	2
53	07	30	51	01	236	-62	-68	+26	+11	0	-20	-16	-18	-42		-57	-62							7	2
53	08	07	51	01	228	-61	-62	+43	+ 9	+ 7	- 6	-12	-34	-34	-49	-52	-53	-61	-93					4	6
53	08	07	51	01	228							-10	-30	-36	-49	-54	-57							4	6
53	08	11	51	01	200			+43	- 6	+10	-47	-11	-51	-39	-56	-58	-73							2	2
53	08	13	51	01	206	-70	-83	+39	-12	+ 9	-17	- 9	-18	-37	-40	-53	-57	-68	-83					2	2
53	08	18	51	01	182			+27	-18	+ 6	-30	-14	-30	-41	-56	-56	-77							7	2
53	08	19	51	01	198			+33	+ 3	+ 5	- 2	-12	-22	-41	-62	-60	-74	-76						7	2
53	09	04	51	01	227	-61	-81	+37	+30	+ 9	-28	-11	-45	-41	-72	-58	-77							7	6
54	01	12	51	01	207	-86		+19	-48	-15	-17	-37	-37	-62	-62	-78	-81	-86						2	5
54	01	19	51	01	206	-82	-90	+34	+10	+ 4	-38	-18	-58	-50	-64	-70	-78	-82	-93	-72	-123	-72	-120	4	2
54	02	04	51	01	275			+ 8	-57	-19	-47	-40	-57	-63	-82									3	2
54	02	22	51	01	205	-84	-87	+33	+12	- 1	-24	-23	-54	-50	-58	-69	-74	-84	-88	-66	-106	-67	-107	4	5
54	02	23	51	02	262	-70	-87	+ 8	- 4	-18	-29	-40	-47	-65	-77	-69	-89	-64	-96					2	2
54	02	24	51	01	262	-62	-90	+17	+ 4	-18	-35	-40	-59	-54	-88	-62	-93	-60	-104	-58	-115	-58	-113	2	3
54	02	25	51	01	250	-60	-92	+12	- 4	-14	-60	-28	-69	-53	-81	-60	-92	-51	-109	-55	-117	-52	-118	1	2
54	03	05	51	01	237	-71	-97	+10	-29	-22	-67	-43	-68	-58	-77	-69	-93	-63	-110	-60	-115	-62	-117	1	2
54	03	10	51	01	227	-69	-89	+22	-25	- 8	-38	-29	-59	-52	-74	-65	-83	-69	-99	-63	-116	-61	-120	2	2
54	03	11	51	01	250	-60	-91	+24	+ 2	- 6	-40	-26	-58	-50	-81	-60	-91	-58	-111	-60	-120	-66	-122	2	5
54	03	22	51	02	228	-69	-79	+33	- 2	0	-26	-20	-25	-52	-53	-66	-73	-71	-88	-58	-110	-56	-117	4	2
54	03	23	51	02	301	-57	-82	+27	-37	-10	-47	-32	-57	-57	-82	-55	-99	-53	-109	-51	-118	-53	-121	2	3
54	04	06	51	01	227	-74	-86	+ 6	-36	-17	-57	-36	-62	-58	-65	-70	-81	-67	-94					1	7
54	05	13	51	01	206	-77	-88	+31	+25	0	- 6	-20	-30	-49	-63	-64	-71	-77	-92					2	2
54	05	25	51	01	227	-67	-86	+25	+12	+ 1	- 2	-20	-21	-48	-49	-64	-76	-61	-93	-54	-118			2	2
54	05	28	51	01	186	-71	-91	+34	+25	+ 4	+ 3	-16	-29	-41	-46	-57	-62	-66	-87					2	2
54	06	10	51	01	265									-51	-74	-49	-88	-47	-107	-45	-116	-45	-118	1	3
54	06	11	51	01	275									-54	-74	-51	-97	-46	-112	-47	-119	-48	-121	1	2
54	06	16	51	01	238	-67	-78	+38	+25	+10	- 3	-13	-29	-42	-58	-62	-74	-59	-97	-60	-110	-58	-110	7	2
54	06	24	51	01	188	-76	-90							-39	-48	-56	-63	-72	-84	-61	-113	-60	-118	6	2
54	06	28	51	01	275									-52	-65	-53	-89	-45	-105	-45	-111			1	3
54	06	29	51	01	250	-57	-84	+33	+12	+ 2	-23	-19	-44	-47	-63	-57	-84	-46	-109	-45	-120	-45	-120	1	6
54	07	01	51	01	238	-60	-79							-45	-45	-57	-72	-56	-102	-52	-116	-52	-119	2	3
54	07	05	51	01	300									-45	-85	-42	-100	-42	-109	-43	-116	-47	-118	1	3
54	07	06	51	01	300	-49	-83	+18	- 3	-15	-35	-35	-52	-49	-83	-43	-98	-42	-109	-43	-113	-47	-116	1	3
54	07	14	51	01	227	-64	-69	+33	-11	+ 4	-51	-13	-41	-39	-56	-57	-62	-66	-94	-54	-117	-56	-119	7	2
54	08	04	51	01	227	-61	-83	+40	+11	+ 9	-10	-14	-30	-44	-57	-57	-74	-51	-95	-57	-111	-59	-119	2	2
54	08	05	51	01	228	-65	-75							-35	-52	-57	-69	-67	-86	-67	-90	-65	-94	2	2

Date			Approximate position		Tropopause			Standard pressure levels																Air mass classification	Circulation classification
								700 mb.		500 mb.		400 mb.		300 mb.		250 mb.		200 mb.		150 mb.		125 mb			
Year	Month	Day	Latitude (°N)	Longitude (°W. except where otherwise stated)	Pressure (mb)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)	Temperature (°F)	Frostpoint (°F)		
54	08	10	51	01	252	-58	-75	+26	+17	- 1	-30	-24	-54	-51	-59	-55	-79	-45	-94	-49	-109	-49	-117	1	2
54	08	11	51	01	262	-53	-80	+30	-12	+ 1	-19	-20	-25	-47	-53	-51	-84	-51	-97	-55	-113	-56	-118	6	2
54	08	17	51	01	227	-61	-84	+39	+27	+ 7	- 4	-11	-28	-42	-67	-58	-70	-57	-97	-59	-114	-61	-119	8	5
54	08	23	51	01	261	-57	-86	+27	+ 8	- 5	-28	-25	-42	-50	-77	-56	-90	-49	-101	-47	-111	-52	-104	2	3
54	08	26	51	01	228	-66	-73	+36	+13	+11	-30	- 9	-36	-39	-61	-59	-68	-66	-82	-60	-107	-66	-112	7	6
54	12	09	51	01	300									-67	-81	-65	-101	-68	-112					1	3
54	12	10	51	01	328	-70	-83	+ 8	-26	-28	-43	-53	-55	-67	-93	-68	-110	-69	-117	-72	-122	-76	-122	1	3
54	12	13	51	01	226	-72	-86			- 5	-20	-26	-36	-51	-59	-67	-82	-69	-100	-69	-113	-74	-116	7	4
54	12	14	51	01	205	-82	-91	+31	-37	0	- 5	-24	-32	-48	-64	-66	-71	-80	-95	-74	-120	-76	-123	4	5
54	12	20	51	01	205	-81	-98	+27	0	- 1	-49	-27	-55	-57	-77	-73	-84	-80	-100	-77	-114	-73	-117	7	2
54	12	21	51	01	187	-95	-98	+24	+18	+ 1	-44	-20	-44	-45	-68	-65	-71	-88	-91	-83	-110			7	2
54	12	22	51	01	170	-97	-109	+27	+15	- 4	-13	-21	-35	-49	-63	-66	-75	-86	-93	-84	-115	-76	-117	7	2
55	02	03	51	00	301	-55	-94	+ 8	-23	-26	-43	-40	-73	-55	-94	-52	-99	-50	-114	-53		-62		2	3
55	02	04	50	00	301	-62	-82	+12	-17	-18	-32	-39	-54	-62	-82	-65	-95	-58	-110	-57	-115			2	2
55	02	07	51	02	235	-73	-77	+24	+ 8	- 3	-22	-24	-38	-53	-66	-69	-75	-74						4	2
55	02	08	51	02	225	-79	-79	+19	- 4	- 4	-14	-24	-40	-54	-73	-71	-75	-81	-96	-73	-116	-70	-118	7	2
55	02	08	51	02	250	-69	-77	+16	-33	- 7	-18	-26	-35	-52	-68	-69	-77	-73	-101	-68	-117	-66	-119	7	2
55	02	09	51	00	301	-61	-82	+15	0	-19	-43	-38	-77	-61	-82	-64	-93	-62	-108	-60	-112	-68		2	4
55	02	11	51	02	370	-58	-72	+ 1	-49	-28	-38	-50	-63	-62	-93	-61	-101	-59	-110	-61	-113	-63	-118	0	7
55	02	14	51	02	275	-69	-91	+11	-55	-21		-41		-63	-81	-70	-93	-70	-102	-60	-109	-61	-111	2	4
55	02	15	51	02	235	-69	-103	+ 7		-23		-42		-60	-78	-67	-98	-63	-111	-66	-115	-63	-119	5	2
55	02	16	51	00	301	-62	-81	+ 7	- 8	-17	-48	-37	-64	-62	-81	-67	-95	-65	-109	-59	-117	-70	-120	1	2
55	02	28	51	01	187	-87	-97	+19		- 5		-23	-32	-53	-68	-71	-75	-84	-92	-78	-114	-79	-118	9	1
55	03	01	51	01	187	-92	-101							-54	-67	-73	-78	-89	-96	-80	-117			9	1
55	03	02	51	01	187	-94	-100							-57	-69	-76	-85	-91	-99	-80	-114	-76	-117	3	1
55	03	03	51	02	187	-88	-100	+23	- 2	- 5	-27	-29	-49	-59	-73	-70	-88	-84	-98	-79	-113			3	1
55	03	04	51	01	206	-91	-97	+22		- 9		-32		-61	-70	-77	-81	-89	-97	-75	-113	-72	-117	1	6
55	03	09	51	02	275	-70	-75	+ 4		-22		-41		-64	-73	-68	-83	-67	-91	-64	-90	-64	-91	6	2
55	03	10	51	01	228															-71	-109	-68	-111	6	2
55	03	10	51	02	285	-67	-73					-37		-63	-69	-74	-84	-76	-95	-70	-105	-74	-102	6	2
55	03	11	51	01	227	-83	-89					-30		-60	-70	-75	-83	-84	-93	-73	-101	-71	-108	6	2
55	03	14	51	01	187	-98	-106					-30		-59	-65	-73	-84	-92	-102	-82	-116	-74	-118	2	1
55	03	15	51	01	175									-62	-71	-77	-81	-89	-93					2	1
55	03	16	51	01	215									-64		-79	-85	-89	-94					2	2
55	03	18	51	02	275	-70	-83	+13	-11	-17	-42	-37	-63	-63	-77	-72	-92	-77	-100	-74	-116	-70	-118	1	2
55	03	18	51	01	301	-64	-73			-15		-38		-64	-73	-74	-92	-75	-103					1	2
55	03	21	51	00	250	-75	-91	+12	-14	-14	-47	-35	-64	-61	-81	-75	-91	-70	-109	-62	-117	-61	-117	1	2
55	03	28	51	01	274	-73	-77					-40	-52	-67	-71	-69	-93							1	2
55	08	30	51	02	215	-65	-91	+34	+17	+ 6	-19	-17	-25	-43	-74	-59	-83	-62	-99	-61	-115	-67	-117	2	2
55	08	31	51	02	250	-63	-77	+28	+19	0	-17	-20	-51	-47	-67	-63	-77	-61	-104	-63	-117	-60	-118	2	2
55	09	29	52	01E	178	-84	-92							-40	-59	-58	-70	-75	-87	-83	-108	-88	-115	7	1
55	10	04	51	01	250	-67	-81							-56	-75	-67	-81	-65	-98	-65	-115	-67	-118	7	7
55	10	12	51	01	197	-77	-92	+28	+14	0	8	-20	-19	-49	-52	-63	-73	-75	-88	-72				4	1
55	10	17	51	01	238	-74	-89	+13	-22	- 9		-33		-54		-69	-85	-70	-100					6	2
55	10	18	51	01	301	-65	-67	+10	-25	-16	-23	-36	-38	-65	-67	-68	-92	-61	-108					6	2
55	10	18	51	01	287	-68	-72					-34	-48	-63	-68	-68	-93	-64	-108	-61	-113	-64	-114	6	2
55	10	20	51	01	287	-60	-76	+20	-18	-13	-22	-32	-52	-56	-72	-51	-95	-48	-106	-57	-110	-63	-112	6	3
55	10	26	51	01	206	-84	-88	+29		- 4		-23		-48	-62	-68	-73	-82						4	2
55	10	28	51	00	287	-63	-83	+10	-13	-15	-54	-34	-62	-59	-78	-65	-92	-69	-102	-66	-115	-66	-117	1	2
55	10	31	51	00	206	-85	-90	+20	0	- 9	-23	-31	-46	-59	-71	-75	-86	-80	-94	-73	-113	-72	-116	6	6
55	11	01	51	00	238	-75	-90	+19	- 7	-12	-22	-35	-46	-61	-81	-72	-85	-71	-104	-71	-113	-70	-116	4	6
55	11	08	51	00	262	-71	-74	+22	+19	-10	-40	-34	-52	-61	-72	-70	-80	-67	-103	-64	-112	-66	-115	2	2
55	11	11	51	02	238	-82	-86	+25		- 6		-27		-59	-67	-78	-83	-75	-104					7	2
55	11	22	51	00	227	-73	-93	+15	-13	-10	-39	-29	-52	-50	-77	-63	-89	-75	-100	-78	-113	-79	-112	2	1
55	11	28	51	00	227	-79	-85	+26		- 7		-29		-59		-74	-81	-79	-94	-74	-113	-75	-117	2	2
55	11	29	50	05	206	-72	-95	+25		- 7		-23		-50	-82	-64	-90	-72	-97	-74	-114	-76	-117	2	2
55	12	01	52	02	227	-64	-99					-36		-55	-84	-62	-92	-65	-107	-69	-115	-70	-120	2	2

Air mass classification key

Code	Type
0	Arctic
1	Polar
2	Polar Maritime
3	Polar Continental
4	Tropical
5	Polar/Arctic
6	Polar Maritime/Polar
7	Tropical/Polar Maritime
8	Tropical/Polar
9	Tropical/Polar Continental

Circulation classification key

Code	Type
1	Anticyclonic
2	Intermediate
3	Cyclonic
4	Intermediate/Cyclonic
5	Cyclonic/Intermediate
6	Intermediate/Anticyclonic
7	Cyclonic/Anticyclonic
8	Anticyclonic/Intermediate
9	Anticyclonic/Cyclonic

In the compound classifications, the first named refers to the upper level, about 300 mb - e.g., Polar/Arctic indicates polar air overlying arctic air; and Cyclonic/Anticyclonic indicates the circulation at 300 mb is cyclonic while that at the surface is anticyclonic.

VEB

H.R.P. 1052

TABLE II

Mean seasonal values of temperature (T) and frostpoint (F) at standard pressure levels

		Winter						Spring						Summer						Autumn					
		Canberra		Pre-Canberra		All observations		Canberra		Pre-Canberra		All observations		Canberra		Pre-Canberra		All observations		Canberra		Pre-Canberra		All observations	
			No. of obs.		No. of obs.		No. of obs.		No. of obs.		No. of obs.		No. of obs.		No. of obs.		No. of obs.		No. of obs.		No. of obs.		No. of obs.		No. of obs.
Tropopause	P_c mb	246.0	38	250.3	68	248.7	106	233.7	10	247.5	107	246.3	117	242.4	14	224.1	81	226.7	95	239.3	23	240.8	58	243.8	81
	T_c °F	-72.9	34	-71.9	55	-72.3	89	-69.9	7	-66.4	91	-66.7	98	-62.0	13	-62.8	59	-62.7	72	-75.3	22	-65.0	41	-68.6	63
	F_c °F	-87.4	33	-86.3	54	-86.7	87	-86.1	7	-79.4	90	-79.9	97	-80.5	13	-77.6	58	-78.1	71	-87.5	22	-80.0	41	-82.6	63
700 mb	T °F	+16.4	28	+15.2	29	+15.8	57	+27.8	6	+23.9	43	+24.4	49	+31.1	10	+33.2	42	+32.8	52	+21.1	18	+24.8	45	+23.7	63
	F °F	-16.8	23	-12.7	20	-14.9	43	+10.5	6	- 1.3	32	+ 0.6	38	+ 6.0	10	+ 7.7	32	+ 7.3	42	- 4.5	13	- 1.1	35	- 2.0	48
500 mb	T °F	-13.9	27	-13.5	65	-13.6	92	0	5	- 6.9	99	- 6.6	104	+ 1.7	10	+ 4.3	71	+ 4.0	81	- 9.1	17	- 5.3	51	- 6.0	68
	F °F	-36.6	23	-36.8	45	-36.7	68	-14.7	6	-27.2	92	-26.4	98	-24.3	10	-19.5	67	-20.1	77	-28.9	14	-27.6	43	-27.9	57
400 mb	T °F	-33.9	32	-33.7	60	-33.8	92	-20.7	6	-25.7	104	-25.4	110	-18.8	10	-15.9	79	-16.3	89	-29.9	21	-27.4	55	-28.1	76
	F °F	-55.0	24	-52.2	53	-51.7	77	-35.8	6	-46.8	100	-46.2	106	-38.4	10	-36.5	75	-36.7	85	-44.8	15	-46.4	50	-46.0	65
300 mb	T °F	-58.6	36	-56.9	68	-57.5	104	-48.1	10	-50.7	106	-50.5	116	-44.0	14	-42.2	79	-42.4	93	-56.0	23	-50.6	58	-52.1	81
	F °F	-74.5	35	-75.7	64	-75.3	99	-60.5	10	-68.1	104	-67.5	114	-63.9	14	-56.5	77	-57.7	91	-72.0	21	-69.9	54	-70.5	75
250 mb	T °F	-68.1	36	-66.5	67	-67.0	103	-58.3	10	-61.3	103	-61.0	113	-55.1	14	-55.5	80	-55.4	94	-67.3	23	-61.0	55	-62.9	78
	F °F	-86.7	36	-87.8	66	-87.5	102	-78.5	10	-81.1	102	-80.8	112	-78.3	14	-73.4	80	-74.1	94	-85.4	23	-82.7	51	-83.5	74
200 mb	T °F	-72.9	35	-71.7	51	-72.2	86	-58.6	10	-67.0	80	-66.0	90	-56.4	14	-62.2	58	-61.4	72	-72.1	23	-70.9	37	-71.4	60
	F °F	-100.9	33	-97.5	49	-98.9	82	-98.0	10	-96.8	78	-96.9	88	-96.9	14	-93.1	56	-93.8	70	-101.0	22	-95.1	33	-97.1	55
150 mb	T °F	-66.3	30	-	-	-66.3	30	-51.0	7	-	-	-51.0	7	-56.6	14	-	-	-56.6	14	-71.3	18	-	-	-71.3	18
	F °F	-113.1	24	-	-	-113.1	24	-115.3	7	-	-	-115.3	7	-111.2	14	-	-	-111.2	14	-114.1	17	-	-	-114.1	17
125 mb	T °F	-65.9	27	-	-	-65.9	27	-51.2	5	-	-	-51.2	5	-58.9	14	-	-	-58.9	14	-71.4	16	-	-	-71.4	16
	F °F	-115.1	25	-	-	-115.1	25	-117.4	5	-	-	-117.4	5	-114.7	14	-	-	-114.7	14	-116.8	16	-	-	-116.8	16

TABLE III

Mean relative humidity (R.H., %) and humidity mixing ratio (r, g/Kg)

Tropopause pressure (mb) / Level (mb)	Winter		Spring		Summer		Autumn		Year	
	248.7		246.3		226.7		243.8		241.4	
	R.H.	r	R.H.	r	R.H.	r	R.H.	r	R.H.	r
	n		n		n		n			
Tropopause	33.2	.0118	37.6	.0203	32.4	.0253	35.0	.0166	34.6	.0179
	87		97		71		63			
700	20.0	.5052	30.7	1.1687	29.4	1.6504	27.6	1.0194	26.6	1.0035
	43		38		42		48			
500	25.8	.1961	32.7	.3654	27.0	.5273	29.0	.3343	28.4	.3363
	68		98		77		57			
400	31.9	.0936	27.7	.1343	30.0	.2452	33.0	.1361	30.7	.1443
	77		106		85		65			
300	28.0	.0236	31.0	.0419	36.4	.0832	27.7	.0337	30.7	.0413
	99		114		91		75			
250	21.1	.0110	23.5	.0187	26.5	.0310	21.7	.0151	23.2	.0177
	102		112		94		74			
200	12.1	.0054	9.1	.0064	8.5	.0083	13.3	.0063	10.5	.0065
	82		88		70		55			
150	2.2	.0021	0.6	.0017	1.4	.0024	2.9	.0019	1.5	.0020
	29		7		14		17			
125	1.9	.0019	0.5	.0016	1.2	.0021	2.3	.0017	1.3	.0019
	25		5		14		16			

n denotes the number of observations. Values for the year were derived by giving equal weight to seasonal values of temperature and frostpoint.

TABLE IV

Weighted mean seasonal and annual temperatures and frostpoints: datum level the tropopause

'n' indicates the number of 'tropopause pressure groups' used to derive the mean

Level	Winter			Spring			Summer			Autumn			Annual				
													All obs.			Canberra obs.	
	T(-°F)	F(-°F)	n	T(-°F)	F(-°F)	n	T(-°F)	F(-°F)	n	T(-°F)	F(-°F)	n	T(-°F)	F(-°F)	n	F(-°F)	n
P_c-150 mb	66.5	105.5	1	50.3	117.4	2	44.0	114.5	1	66.0	114.0	1	59.2	110.9	5	112.9	3
P_c-125 mb	61.1	111.9	2	46.7	116.3	3	52.7	113.3	2	63.9	114.3	2	56.9	111.5	6	112.9	4
P_c-100 mb	63.0	111.2	4	47.6	113.1	3	56.2	112.6	3	59.0	111.9	4	56.5	108.3	6	111.5	5
P_c- 75 mb	71.1	110.5	6	55.9	111.2	5	57.2	109.2	5	65.1	108.7	5	62.5	107.8	7	106.4	6
P_c- 50 mb	71.0	104.5	6	59.5	103.9	5	59.2	103.5	6	70.4	103.1	6	67.3	105.7	12	104.6	12
P_c- 25 mb	74.6	98.2	6	63.6	93.4	5	61.2	93.8	6	72.4	95.9	7	70.1	96.9	12	101.4	12
P_c mb	77.9	90.6	6	70.0	83.0	6	66.6	79.8	7	74.7	87.6	7	73.1	85.7	12	88.6	12
P_c+ 25 mb	72.7	85.2	7	63.2	75.8	7	59.2	72.6	7	65.7	79.0	7	65.7	77.9	12		
P_c+ 50 mb	66.3	78.3	7	56.1	69.1	7	51.6	67.5	7	59.1	72.8	7	58.3	71.1	12		
P_c+ 75 mb	59.2	72.6	7	48.5	63.0	7	43.4	58.6	7	51.4	66.0	7	50.7	64.2	12		
P_c+100 mb	51.8	65.8	7	41.5	58.1	7	35.7	52.7	7	44.1	59.6	7	43.6	58.8	12		
P_c+125 mb	44.8	61.2	7	34.7	52.9	7	28.8	46.4	6	37.2	53.5	7	36.3	53.1	12		
P_c+150 mb	36.5	55.5	7	27.9	47.4	7	22.3	41.8	6	30.8	48.2	7	30.3	47.4	12		

TABLE V

A

The evaluation of $r = r_o + (r_t - r_o)\exp -wz/K$

(which is the solution to Brewer's eqn. $K\frac{\partial^2 r}{\partial z^2} + w\frac{\partial r}{\partial z} = 0$)

z is the height above the tropopause

Computed values of r (g/Kg)

z \ w/K	1.0	1.5	1.0	1.5	1.0	1.5	1.0	1.5	$\times 10^{-5}$ c.g.s. units
	Winter r_o = .00250 r_t = .00939		Spring r_o = .00210 r_t = .01685		Summer r_o = .00251 r_t = .02328		Autumn r_o = .00250 r_t = .01389		g/Kg g/Kg
5 Km	.00255	.00250	.00220	.00211	.00265	.00252	.00258	.00251	
4 Km	.00263	.00252	.00237	.00214	.00289	.00256	.00271	.00253	
3 Km	.00284	.00258	.00283	.00226	.00354	.00274	.00307	.00263	
2 Km	.00343	.00284	.00409	.00283	.00531	.00354	.00404	.00307	
1 Km	.00504	.00404	.00753	.00539	.01015	.00714	.00669	.00504	
0.5 Km	.00668	.00576	.01105	.00908	.01512	.01233	.00941	.00789	
0	.00939	.00939	.01685	.01685	.02328	.02328	.01389	.01389	

B Observed mean humidity mixing ratio (datum level the tropopause)

	Winter			Spring			Summer			Autumn		
	F(°C)	e_s(mb)	r(g/Kg)	F	e_s	r	F	e_s	r	F	e_s	r
(P_c-150)*	-80.5	.000504	.00395	-	-	-	-83.2	.000321	.00263	-82.4	.000367	.00279
P_c-150	-76.4	.000979	.00767	-83.0	.000332	.00249	-81.4	.000434	.00356	-81.1	.000456	.00346
P_c-125	-79.9	.000556	.00331	-82.4	.000367	.00211	-80.7	.000487	.00300	-81.3	.000441	.00257
P_c-100	-79.6	.000584	.00281	-80.6	.000496	.00232	-80.3	.000521	.00258	-79.9	.000556	.00262
P_c-75	-79.2	.000624	.00251	-79.6	.000584	.00230	-78.4	.000710	.00293	-78.2	.000734	.00291
P_c-50	-75.8	.001076	.00373	-75.5	.001128	.00383	-74.7	.001279	.00453	-74.3	.001360	.00465
P_c-25	-72.3	.001850	.00563	-69.7	.002734	.00817	-69.1	.002988	.00925	-70.3	.002501	.00752
P_c	-68.1	.003460	.00939	-63.9	.006313	.01685	-61.8	.008452	.02328	-65.3	.005180	.01389
Tropopause height (P_c)	229.4 mb			233.0 mb			225.8 mb			231.9 mb		

In three seasons, only one tropopause group extends to P_c-150 mb, (P_c-150)* represents the value computed by applying the lapse of this group to the mean value at P_c-125 mb.

e_s is the saturation vapour pressure.

F(°F) at these levels are given in Table IV, °C are used here so that all units in this table are in the c.g.s. system.

TABLE VI

Ratio of frostpoint lapse ($\delta F/\delta z$) above and below the tropopause

(based on 25 mb finite difference)

Suffix A refers to above the tropopause, and suffix B to below

Pressure Group	Winter			Spring			Summer			Autumn			Annual		
	$\frac{\partial F}{\partial z}/A$	$\frac{\partial F}{\partial z}/B$	Ratio $^{A}/_{B}$	$\frac{\partial F}{\partial z}/A$	$\frac{\partial F}{\partial z}/B$	Ratio $^{A}/_{B}$	$\frac{\partial F}{\partial z}/A$	$\frac{\partial F}{\partial z}/B$	Ratio $^{A}/_{B}$	$\frac{\partial F}{\partial z}/A$	$\frac{\partial F}{\partial z}/B$	Ratio $^{A}/_{B}$	$\frac{\partial F}{\partial z}/A$	$\frac{\partial F}{\partial z}/B$	Ratio $^{A}/_{B}$
4	2.1	1.9	1.1	3.0	1.7	1.8	-	-	-	1.9	2.8	.7	2.7	1.9	1.4
5	1.4	2.1	.6	-	-	-	3.7	2.9	1.3	2.2	2.3	1.0	2.7	2.6	1.0
6	1.5	2.0	.8	2.7	2.6	1.0	3.5	2.9	1.2	1.7	2.6	.7	2.6	2.3	1.1
7	2.2	1.9	1.1	3.3	3.1	1.1	3.3	4.0	.8	2.0	1.9	1.0	3.2	2.7	1.2
8	2.6	1.6	1.7	3.6	2.5	1.4	2.9	2.9	1.0	4.0	2.7	1.5	3.8	3.1	1.2
9	1.6	2.9	.6	3.4	3.3	1.0	4.1	2.6	1.5	2.9	2.6	1.1	2.5	3.3	.8
10	-	-	-	-	-	-	-	-	-	-	-	-	2.2	3.3	.7
11	-	-	-	-	-	-	-	-	-	-	-	-	1.7	3.5	.5
12	-	-	-	-	-	-	-	-	-	-	-	-	1.6	2.2	.7

$\frac{\partial F}{\partial z}$ in units of 10^{-2} $^{\circ}Fm^{-1}$

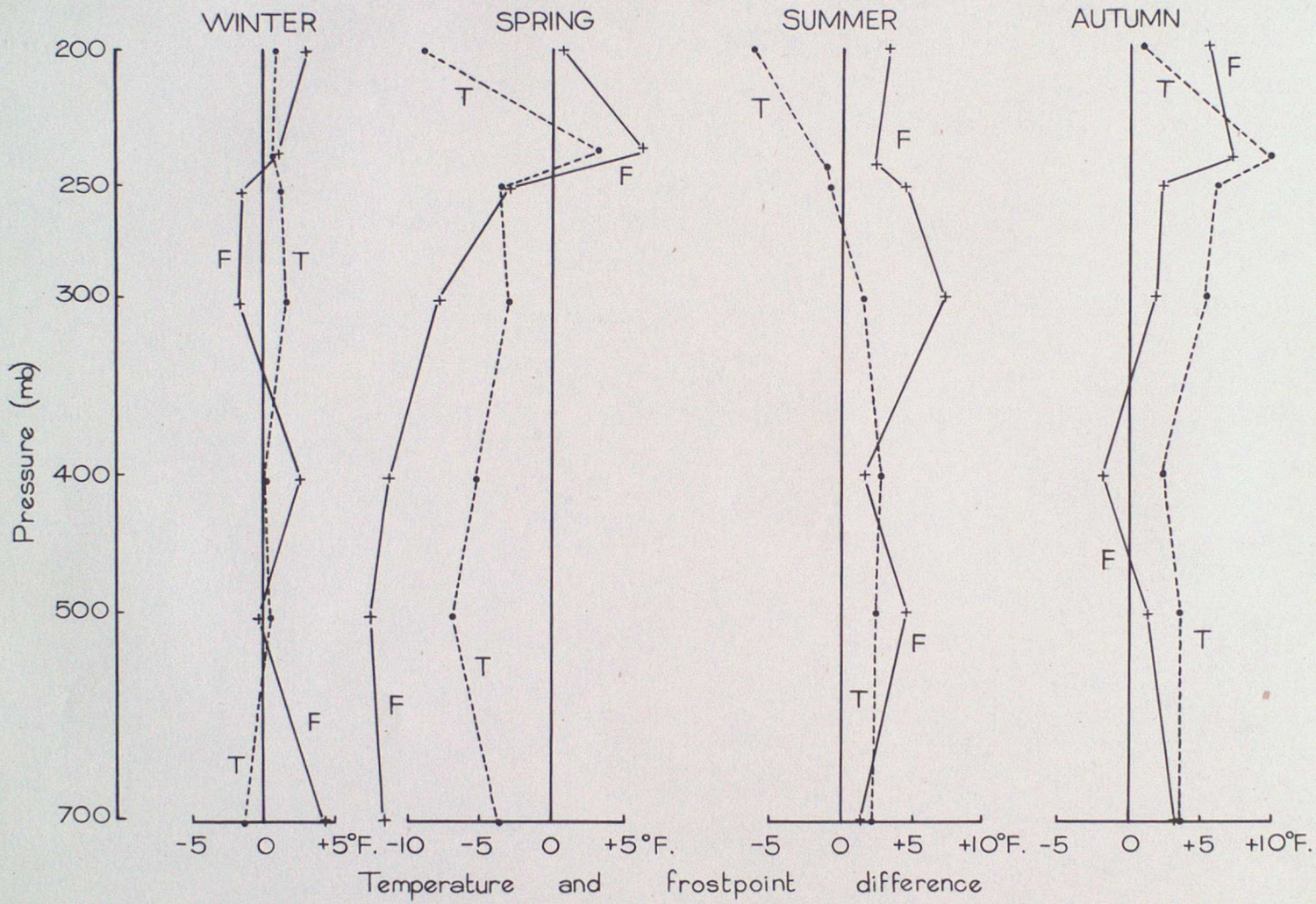

Fig. 1. Difference between Pre-Canberra and Canberra mean values of temperature (T.) and frostpoint (F.) Where the Pre-Canberra value is warmer, the difference is designated positive.

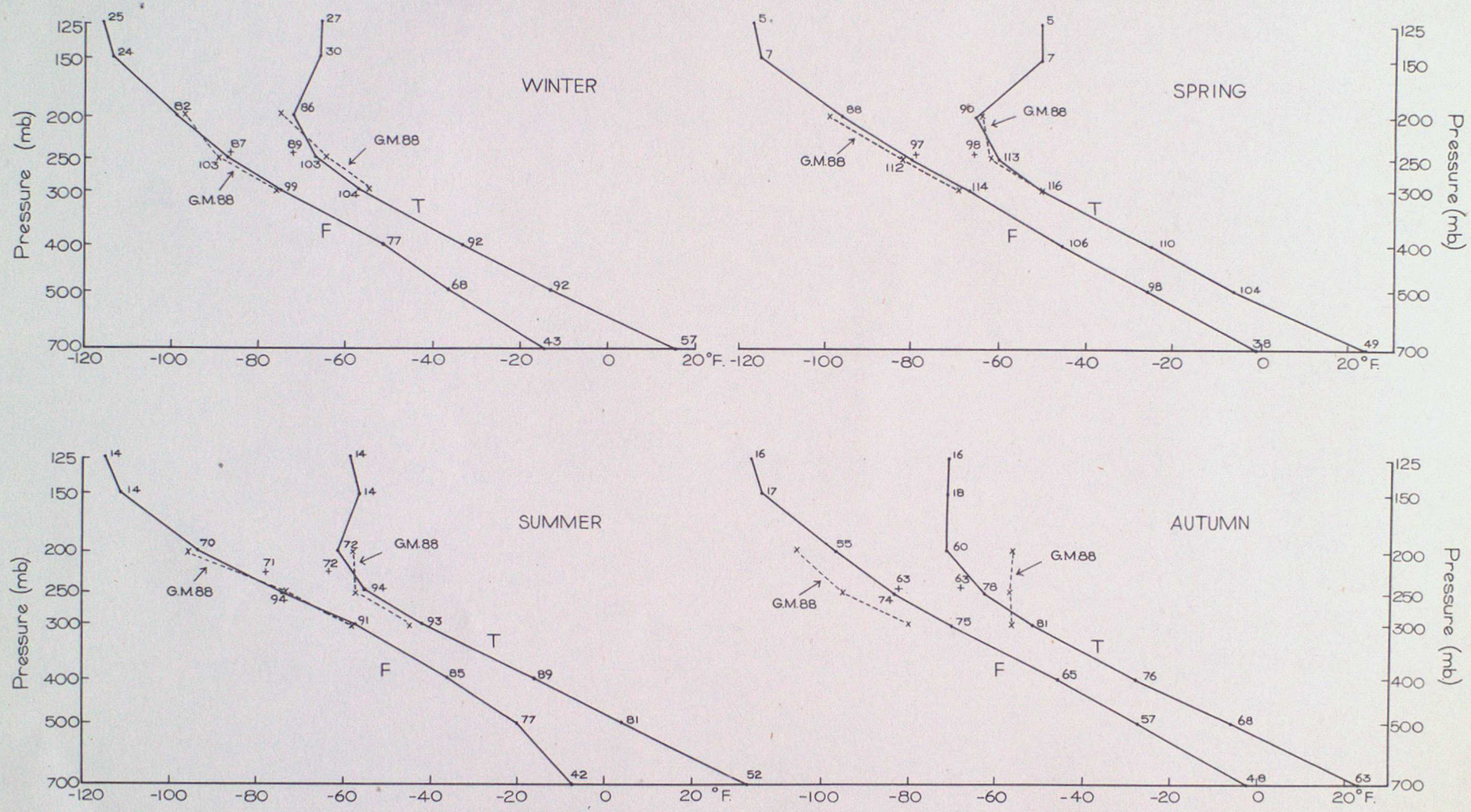

Fig. 2. MEAN SEASONAL VALUES OF TEMPERATURE (T) AND FROSTPOINT (F) AT STANDARD PRESSURE LEVELS

+ marks mean tropopause values. Number of observations is entered alongside points. x marks G.M.88 values.

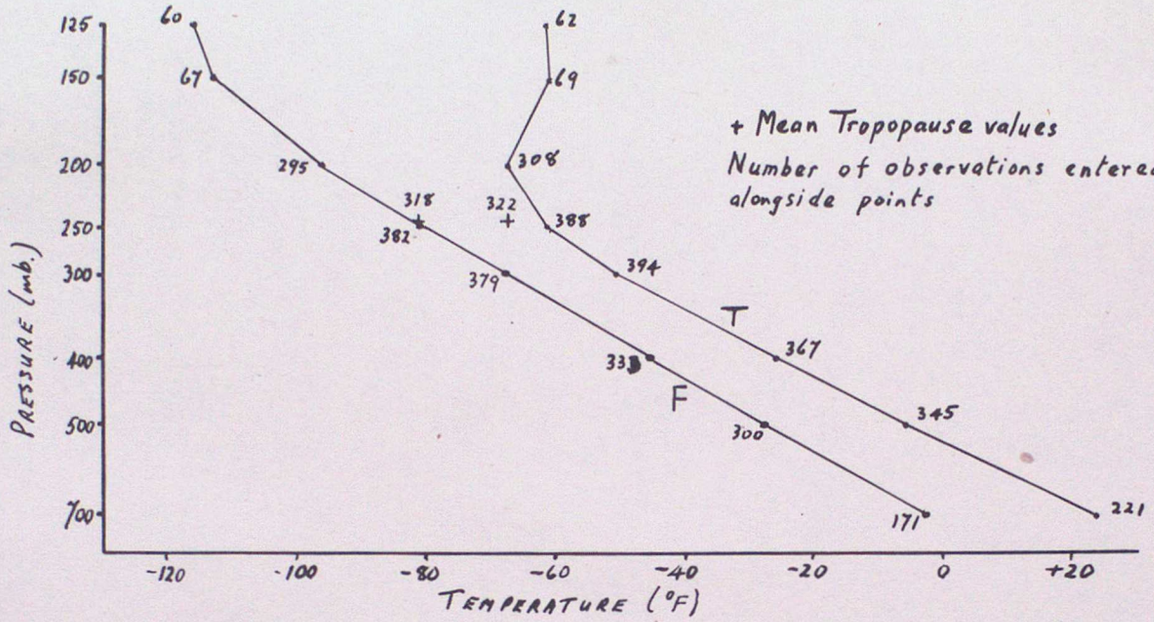

FIGURE 3

MEAN ANNUAL TEMPERATURE (T) AND FROSTPOINT (F).

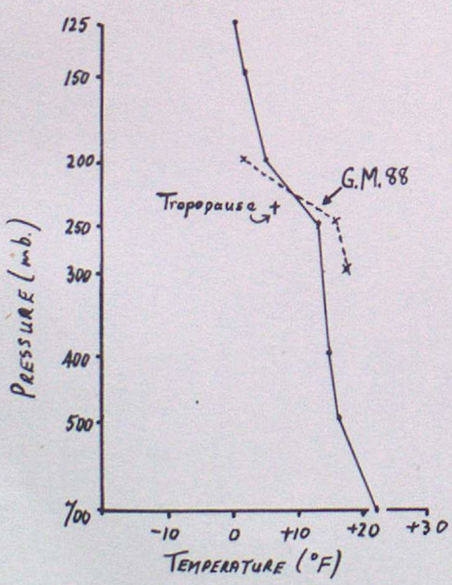

FIGURE 4

FROSTPOINT DIFFERENCES
SUMMER MINUS WINTER

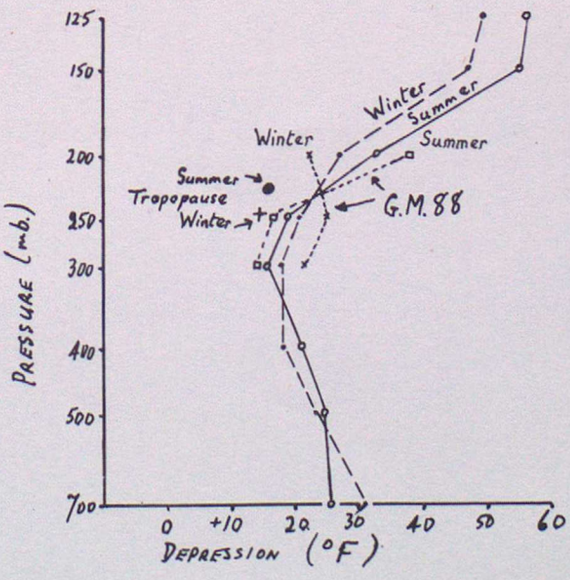

FIGURE 5

FROSTPOINT DEPRESSION

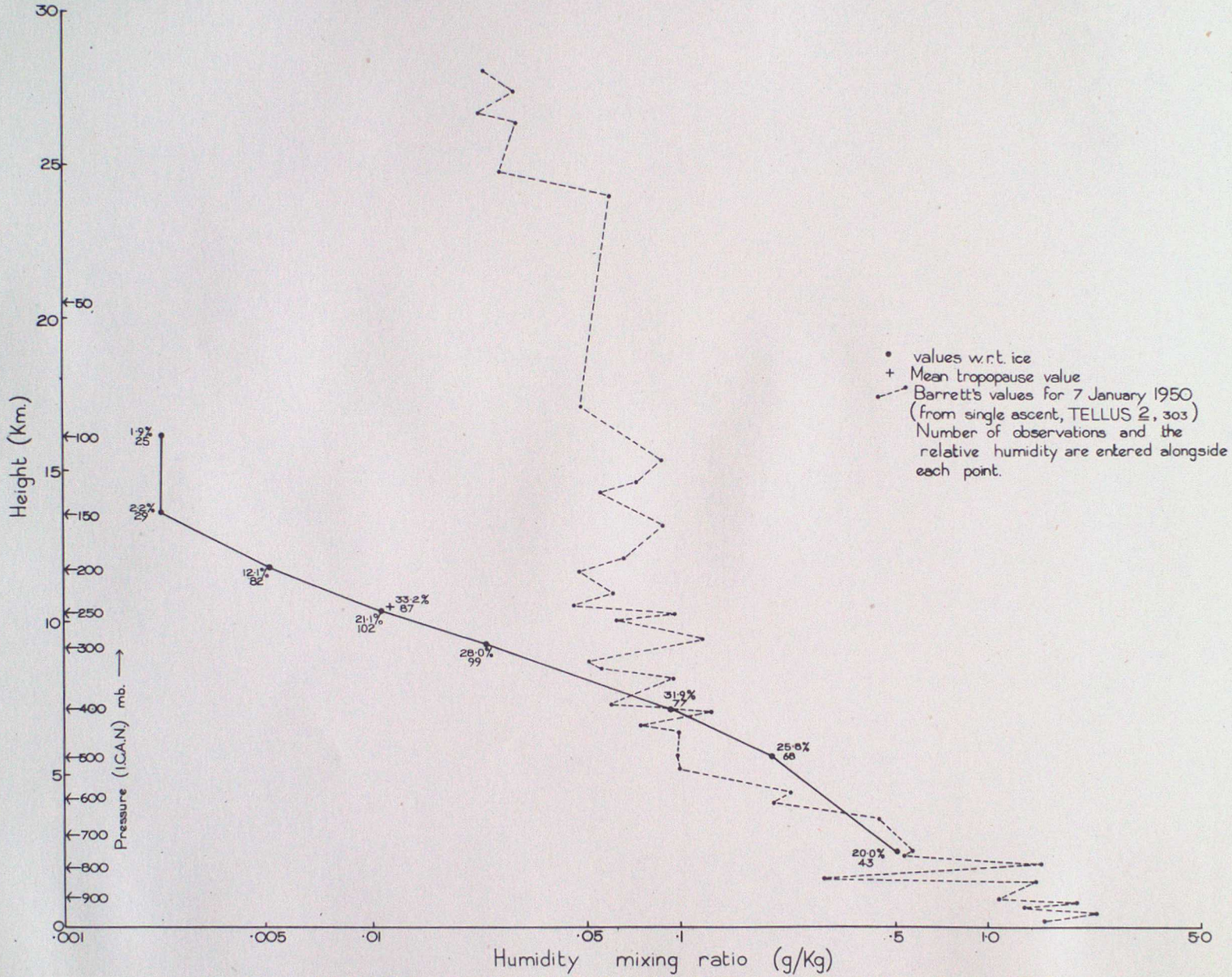

Fig. 6a. VARIATION OF HUMIDITY MIXING RATIO WITH HEIGHT IN THE TROPOSPHERE AND LOWER STRATOSPHERE IN WINTER.

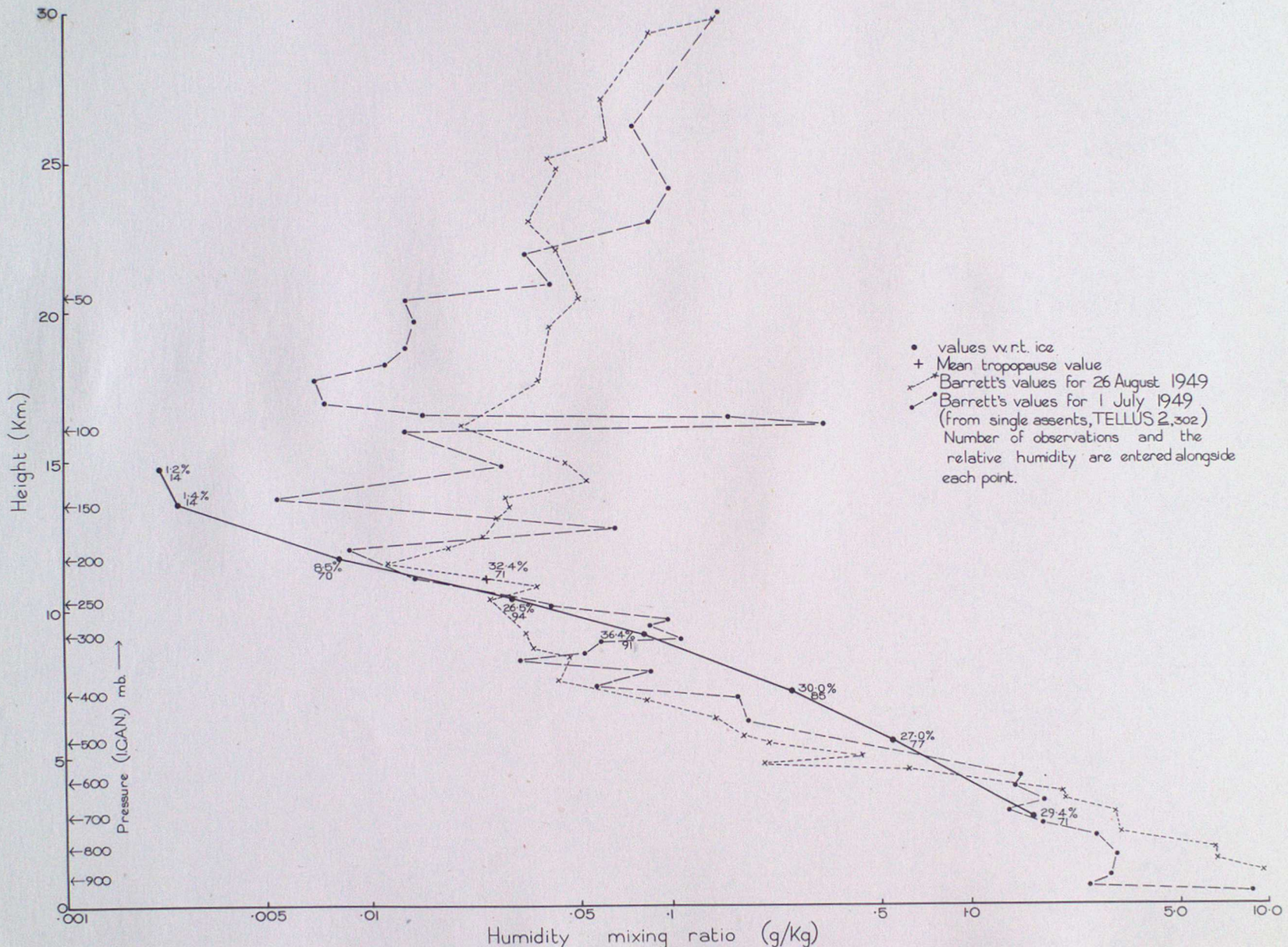

Fig. 6b. VARIATION OF HUMIDITY MIXING RATIO WITH HEIGHT IN THE TROPOSPHERE AND LOWER STRATOSPHERE IN SUMMER.

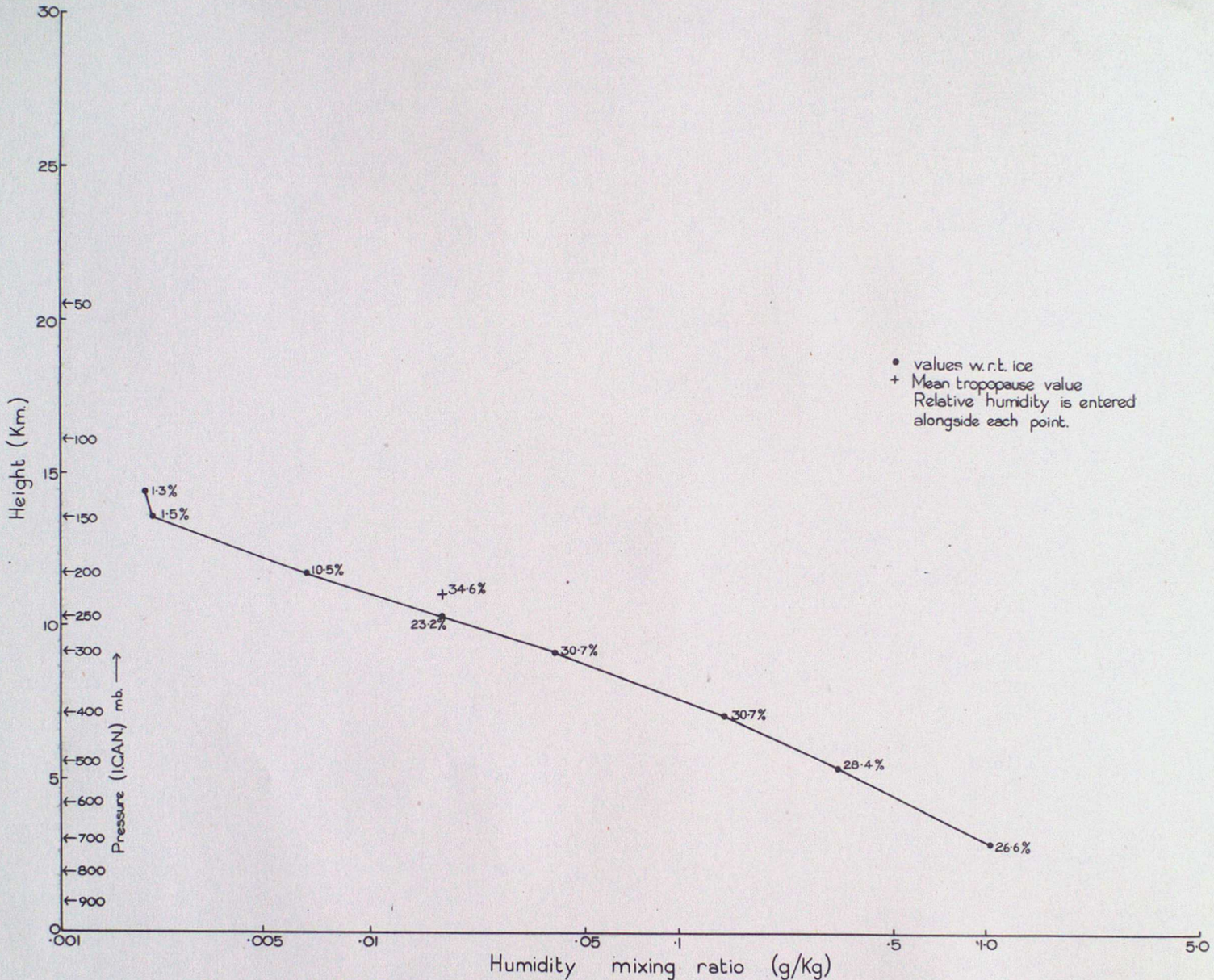

Fig. 6c. VARIATION OF HUMIDITY MIXING RATIO WITH HEIGHT IN THE TROPOSPHERE AND LOWER STRATOSPHERE: ANNUAL MEAN

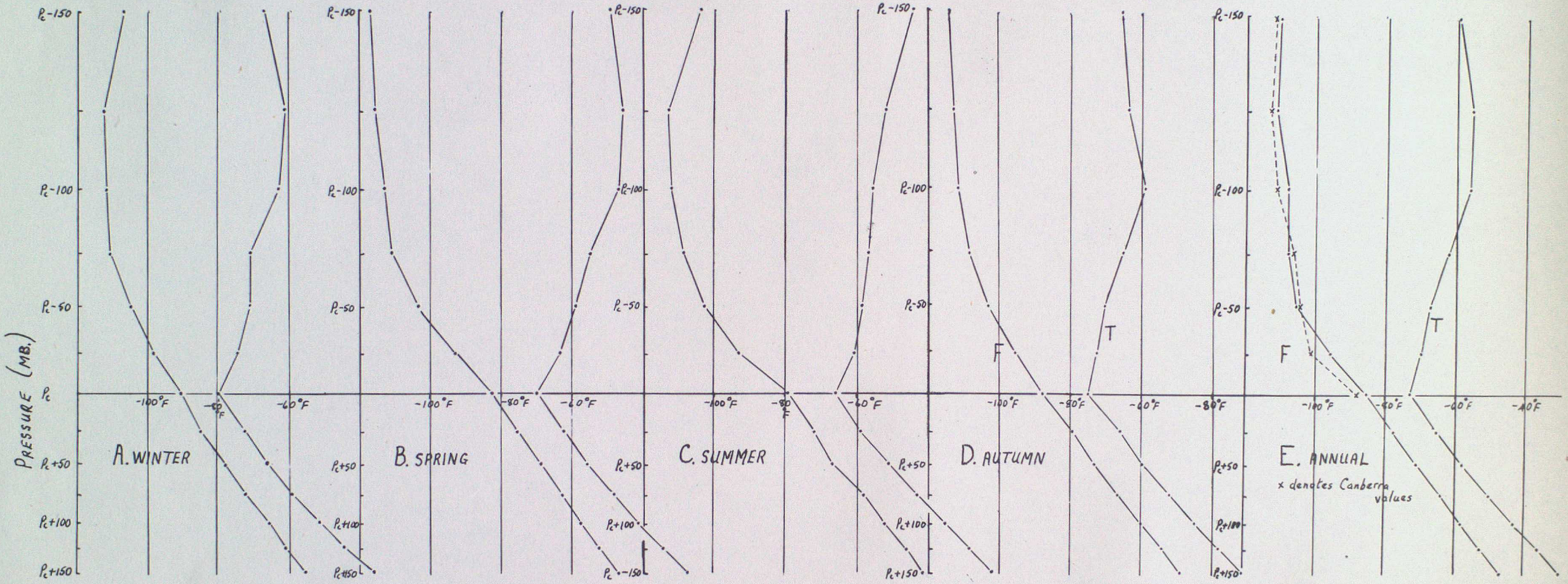

FIGURE 7.

MEAN SEASONAL AND ANNUAL TEMPERATURE (T) AND FROSTPOINT (F) USING THE TROPOPAUSE AS A DATUM LEVEL.

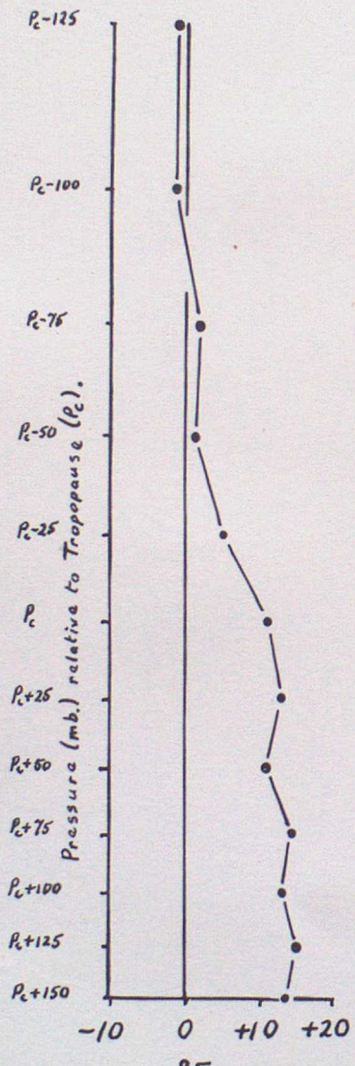

FIGURE 8 A

Summer minus Winter Frostpoint Difference.

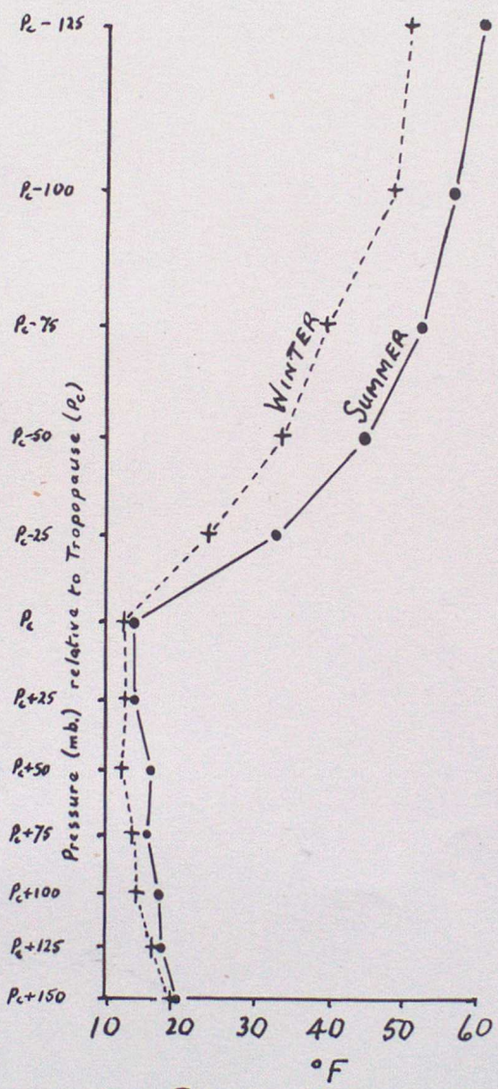

FIGURE 8 B

Summer and Winter Frostpoint Depression.

Datum Level the Tropopause.

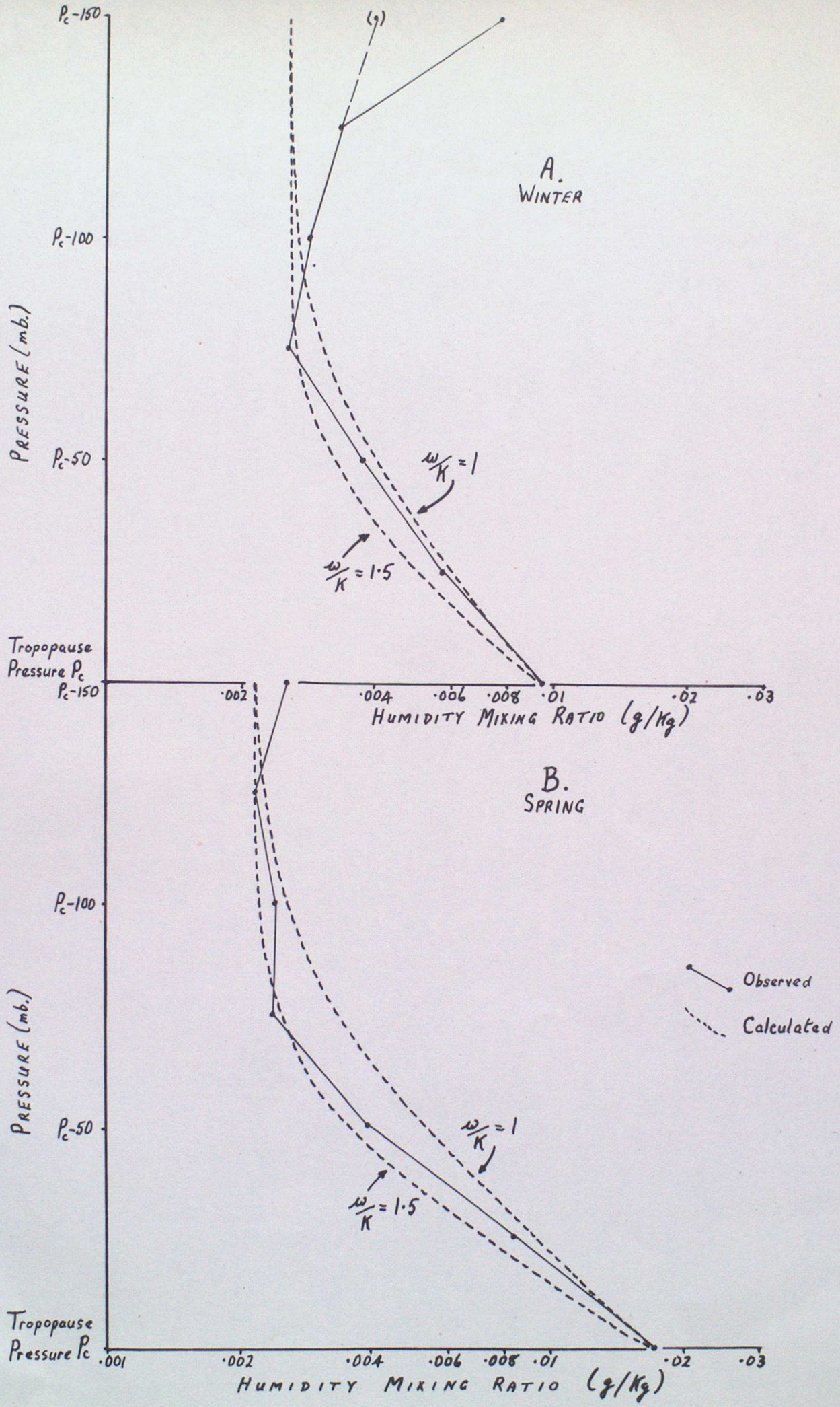

FIGURE 9

MEAN HUMIDITY MIXING RATIO (g/Kg) USING TROPOPAUSE AS DATUM LEVEL.

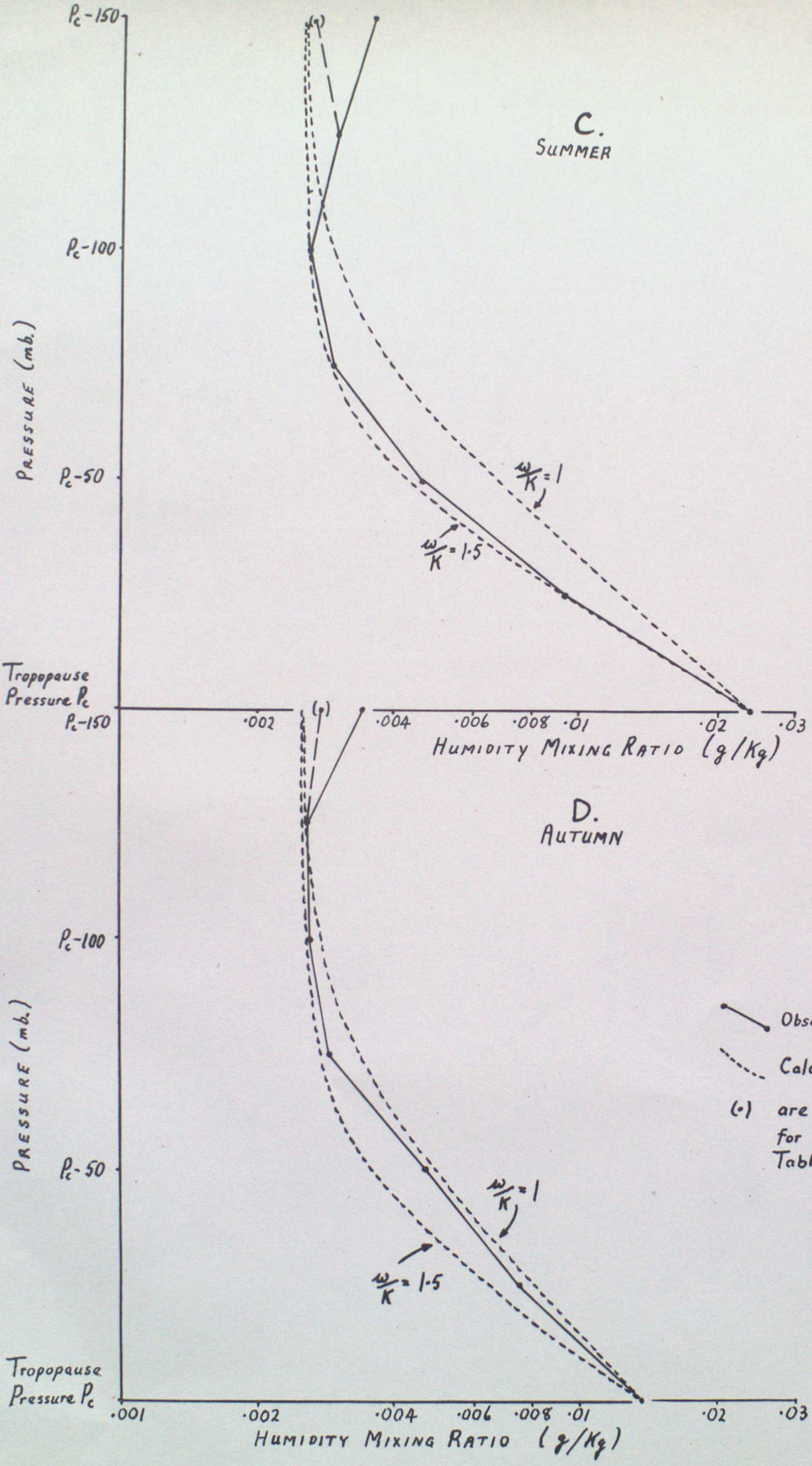

FIGURE 9.

MEAN HUMIDITY MIXING RATIO (g/Kg) USING TROPOPAUSE AS DATUM LEVEL.

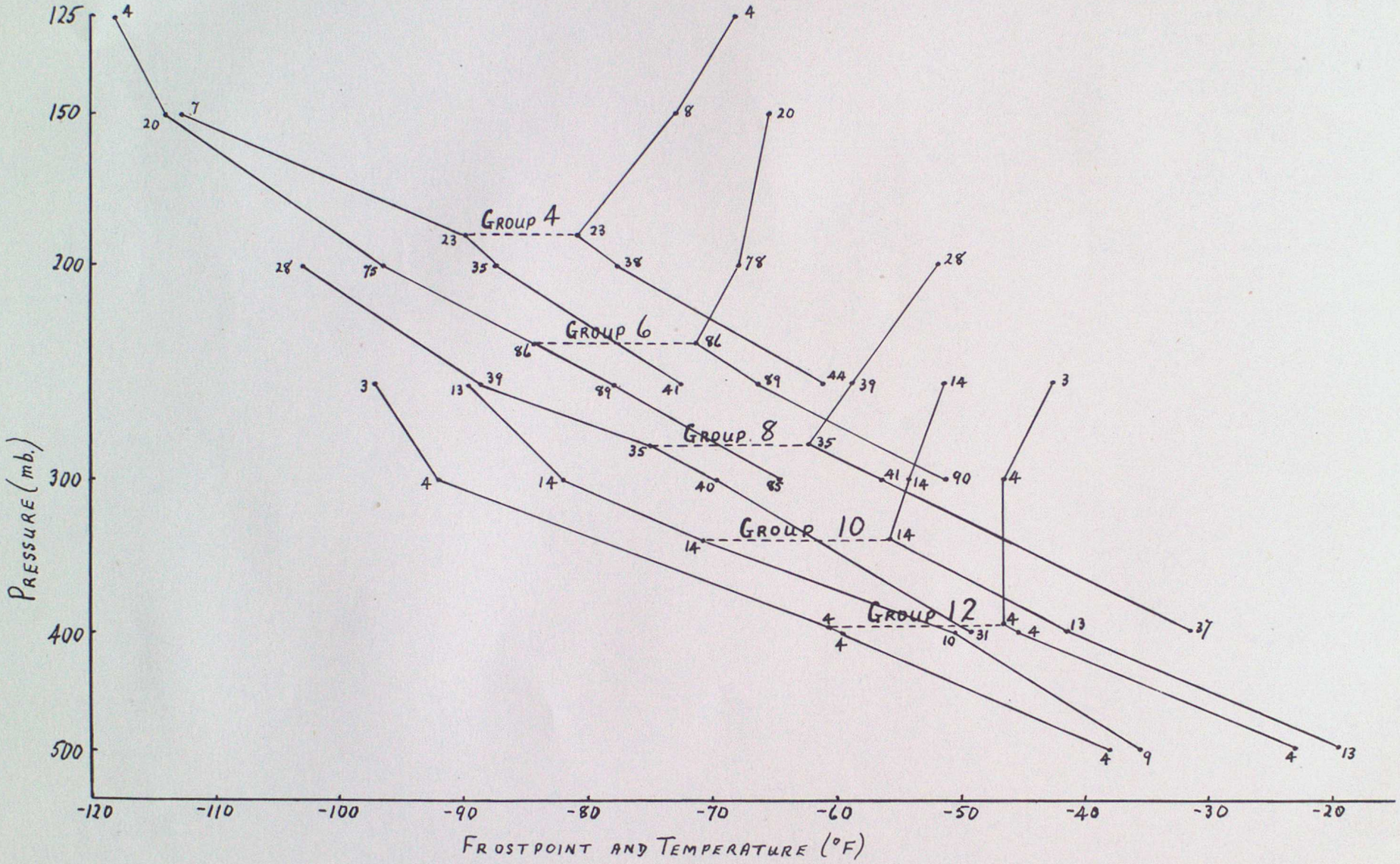

FIGURE 10.

THE EFFECT OF TROPOPAUSE HEIGHT ON THE VERTICAL STRUCTURE OF TEMPERATURE AND FROSTPOINT.
MEAN ANNUAL CURVES FOR VARIOUS TROPOPAUSE PRESSURE GROUPS. (Number of observations entered alongside points).

M.R.P. 1052

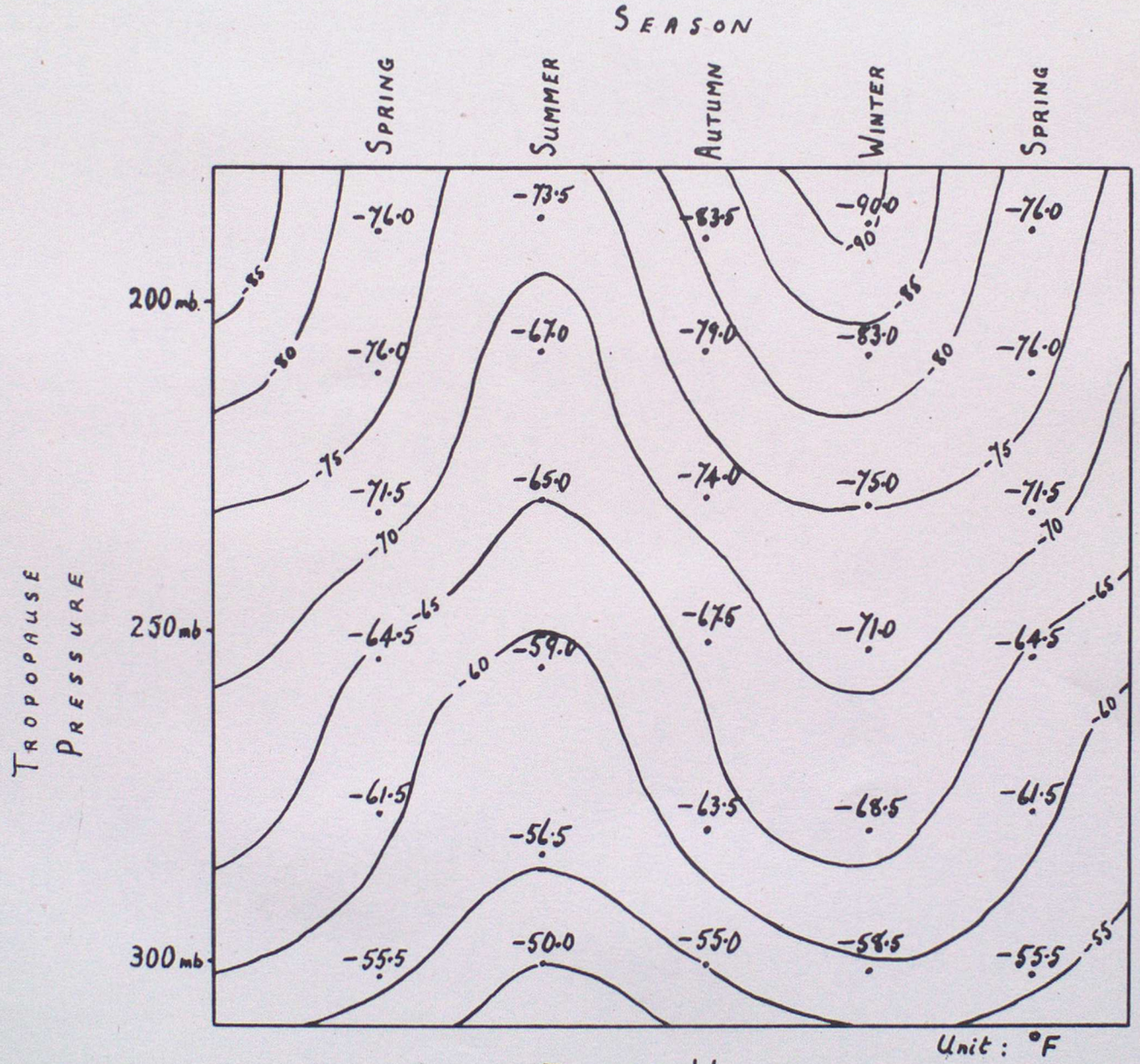

FIGURE 11.

TROPOPAUSE TEMPERATURE : VARIATION WITH PRESSURE AND SEASON.

M.R.P. 1052

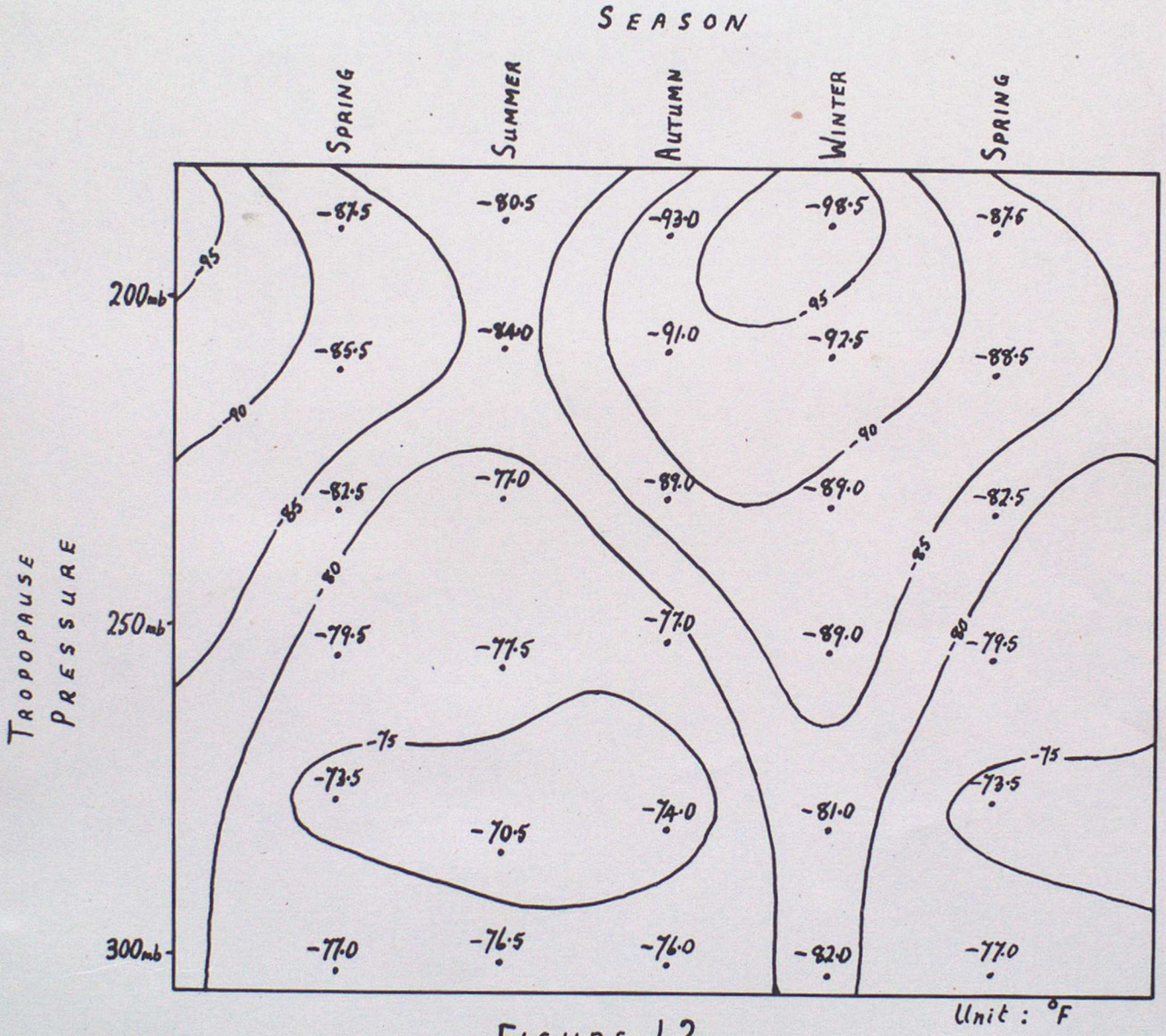

FIGURE 12

TROPOPAUSE FROSTPOINT : VARIATION WITH PRESSURE AND SEASON.

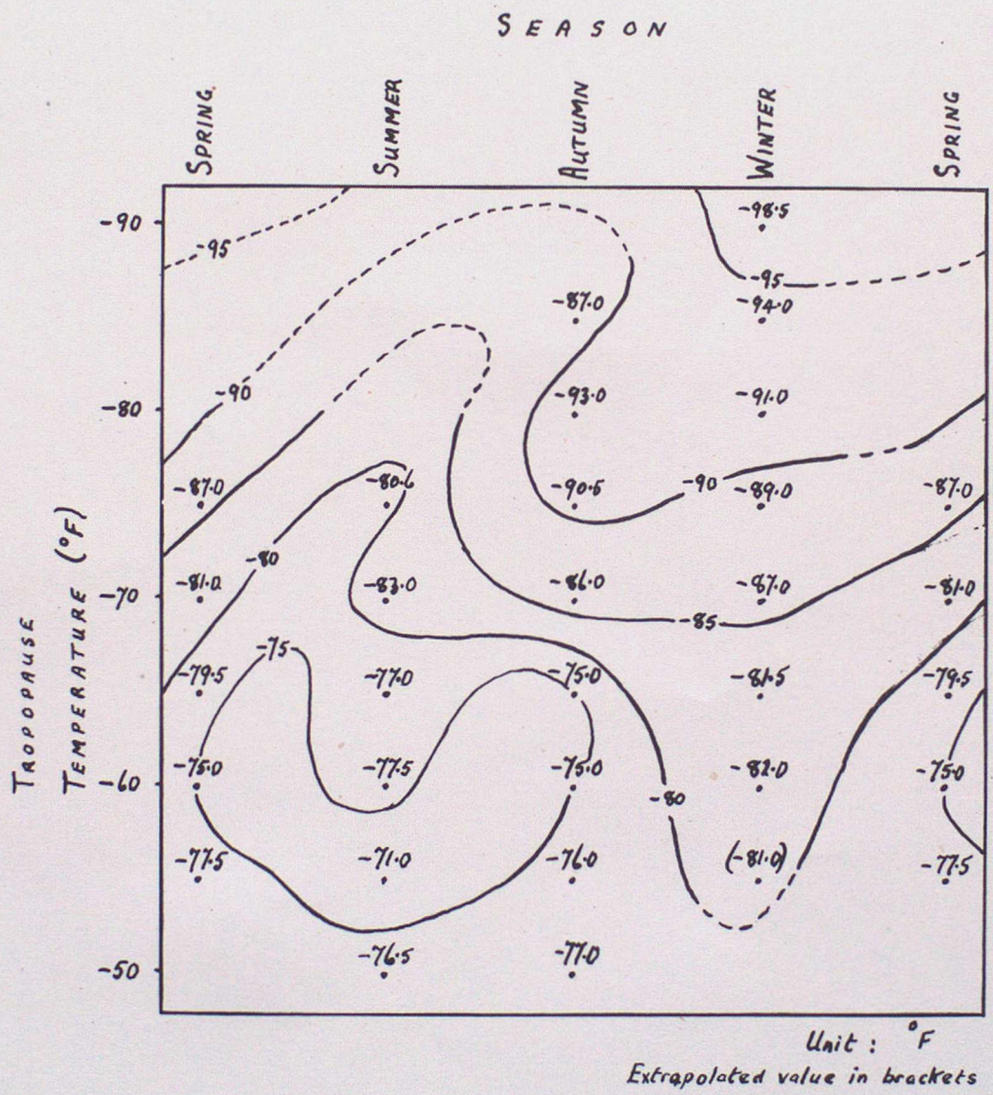

FIGURE 13

TROPOPAUSE FROSTPOINT : VARIATION WITH TEMPERATURE AND SEASON.

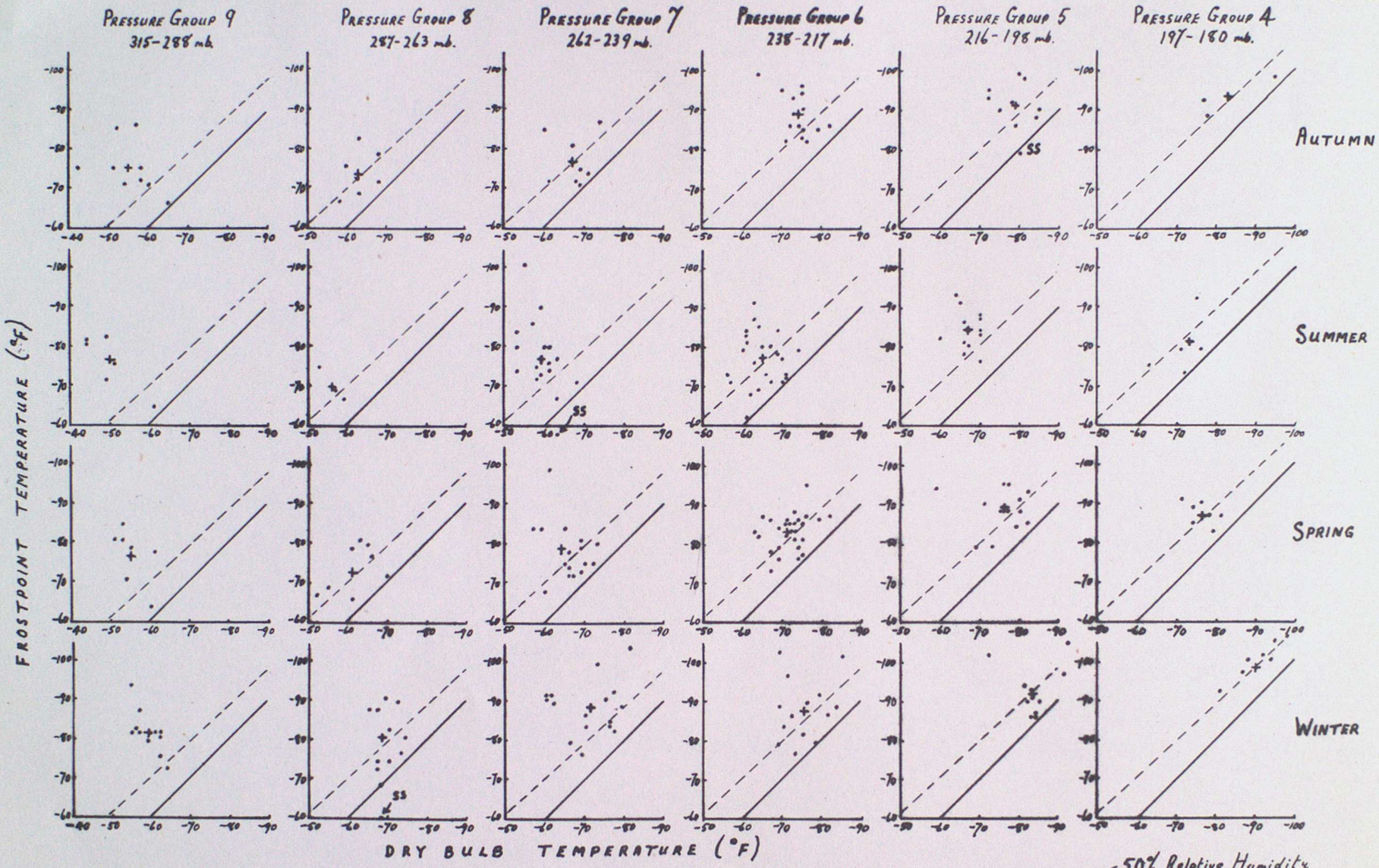

FIGURE 14.

FROSTPOINT AND TEMPERATURE AT THE TROPOPAUSE IN TROPOPAUSE PRESSURE/SEASON GROUPINGS.

M.R.P. 1052

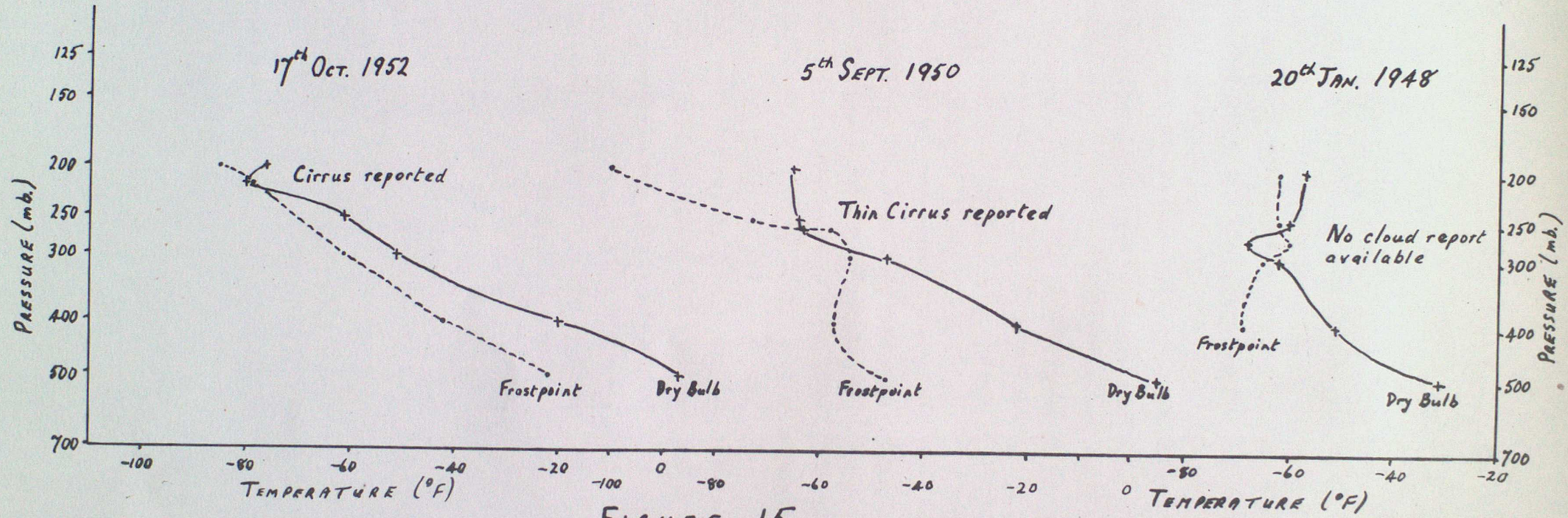

FIGURE 15

ASCENTS WHERE SUPERSATURATION AT THE TROPOPAUSE WAS REPORTED.

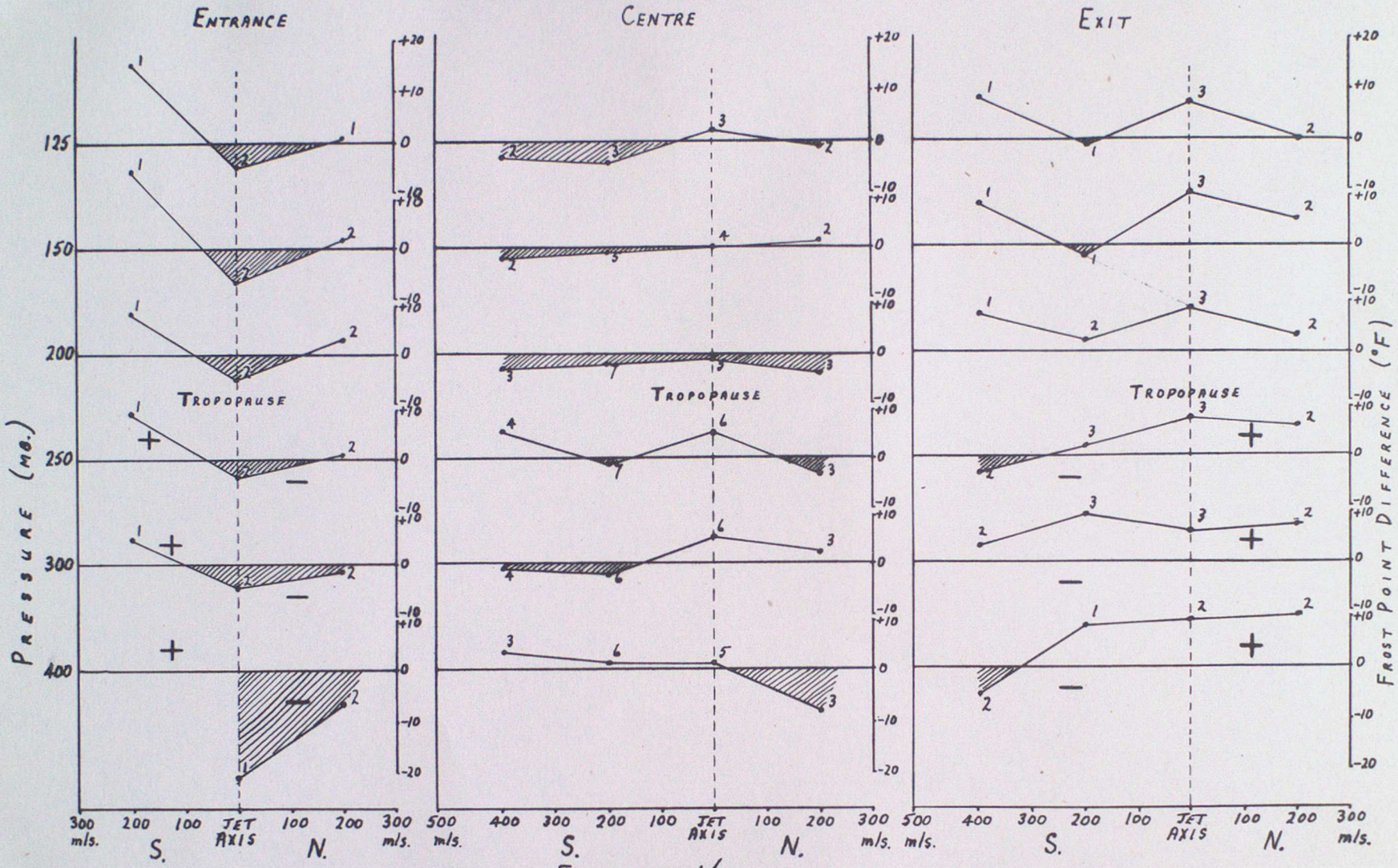

FIGURE 16.

FROST POINT DIFFERENCES FROM "AVERAGE" ABOUT THE JET STREAM.

Negative (shaded) values refer to a lower frost point than average (ie. drier) and suggest downward vertical motion. Positive values suggest upward motion. Figures alongside points indicate the number of cases considered. Signs indicate the "classical" picture of vertical motion (see text). Position in relation to the 300 mb. JET AXIS is the abscissae.

M.R.P. 1052

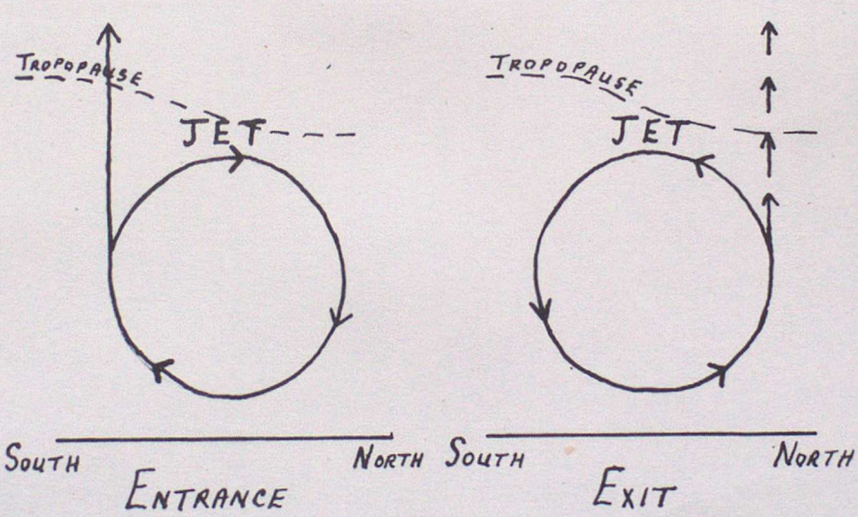

FIGURE 17

CIRCULATION ABOUT THE JET STREAM AXIS AS SUGGESTED FROM FROST POINT DATA (Deduced from Figure 13).